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AH-1F INSTRUMENT METEORLOGICAL CONDITIONS (IMC) FLIGHT EVALUATIONS

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The U.S. Army Aviation Engineering Flight Activity conducted an instrument meteorological conditions (IMC) flight evaluation of the AH-1F helicopter, which included implementation of configuration and procedural changes in an attempt to qualify the aircraft for IMC flight. The test aircraft was configured with the K747 main rotor blades, two tube-launched, optically-tracked, wire command link (TOW) missile launchers with four TOW missiles on each outboard wing store station, and a 19-tube rocket launcher on each inboard wing store station. The test consisted of 105.4 flight hours which were flown during 70 test flights. Four deficiencies and seven shortcomings associated with flying the AH-1F in IMC were identified. The deficiencies were: (1) the easily excited lateral gust response; (2) the unsatisfactory location of avionics controls; (3) the poor cyclic flight control system mechanical characteristics; and (4) the large change in airspeed position error in climbs. The AH-1F is unacceptable for flight in IMC. Modifications evaluated in an attempt to correct the aircraft deficiencies included use of the air data system as a pitot-static source, reduction of cyclic control friction, reduction of cyclic centering spring preloads, addition of a Gurney flap to the vertical stabilizer, removal of the 90-degree gearbox fairings, addition of a ventral fin, changes in pitch and roll stability and control augmentation system gains, addition of attitude holds in the pitch and roll

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axes, and changes in cockpit avionics configurations. The AH-1F is acceptable for flight in IMC when the following modifications are incorporated: attitude hold capability in the pitch and roll axes, cyclic control friction adjusted to 1.0 pounds, and cyclic centering spring preloads adjusted to 3.0 pounds. The suitability of the AH-1F for flight in IMC is enhanced with VOR navigation and VHF communication control panels installed at the copilot/gunner station. In this configuration, the test aircraft was flown in actual IMC and a user evaluation was conducted. These modifications should be incorporated prior to qualification of the AH-1F for IMC flight.

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INTRODUCTION

BACKGROUND

1. All AH-1 series helicopters are currently restricted from instrument meteorological conditions (IMC) flight. The AH-1G was originally evaluated by the U.S. Army Aviation Engineering Flight Activity (AEFA) for instrument flight in the mid 1970's (ref 1, app A). The AH-1G exhibited marginal handling qualities characteristics and lacked an adequate backup electrical supply, which resulted in its restriction from flight under IMC. The 10 Kilovolt-Ampere alternator and transformer rectifier incorporated into the AH-1E, previously designated AH-1S(ECAS), provided adequate backup electrical power, and previous tests indicated that the stability and control characteristics of the AH-1E and the AH-1P, previously designated AH-1S(PROD), are essentially the same. Hence in 1980 the AH-1P was evaluated for instrument flight by AEFA (ref 2). The AH-1P had other significant configuration changes which included different armament, a flat plate canopy, and a higher gross weight. Four deficiencies and seven shortcomings were identified during AEFA Project No. 79-08, which precluded qualification of the AH-1E for IMC flight. This prior testing of the AH-1G and AH-1P indicated that changes in the control system friction, pitot-static systems, location of avionics control heads, operational IMC procedures, and the Stability and Control Augmentation System (SCAS) roll control gains could result in qualification of the AH-1F for IMC flight. Consequently, the U.S. Army Aviation Systems Command (AVSCOM) tasked AEFA to conduct an evaluation of the AH-1F. AEFA was further tasked to make configuration and procedural changes in an attempt to qualify the helicopter for IMC flight (ref 3).

TEST OBJECTIVE

2. The objective of this test was to conduct an IMC flight evaluation of the AH-1F and make authorized configuration changes in an attempt to qualify the helicopter for IMC flight.

DESCRIPTION

3. The AH-1F is a two-place, tandem seat, single-engine attack helicopter incorporating skid landing gear and two-bladed teetering main and anti-torque rotors. It is manufactured by Bell Helicopter Textron, Inc. (BHTI) and powered by an Avco Lycoming T53-L-703 turboshaft engine with an uninstalled thermal rating of 1800 shaft horsepower limited to 1290 by the transmission. The maximum gross weight of the AH-1F is 10,000 pounds. Distinctive features of the helicopter include the narrow fuselage, stub wings with four stores stations, and a flat-plate canopy. A more detailed description of the AH-1F may be found in appendix B and in the operator's manual (ref 4, app A).

4. The test aircraft AH-1F U.S. Army Serial Number 69-16423 was configured with the K747 main rotor blades, two M65 tube-launched, optically-tracked, wire command link (TOW) missile launchers with four dummy TOW missiles on each outboard store station, and an M159C 19-tube rocket launcher on each inboard store station. The aircraft underwent specified configuration changes during the evaluation as described in appendix B.

TEST SCOPE

5. The IMC flight evaluation was conducted at Edwards Air Force Base, California, and at nearby airfields with instrument approach facilities. A total of 70 flights were conducted between 6 September 1984 and 2 October 1987 consisting of 105.4 flight hours of which 71.9 were productive. AEFA installed, calibrated, and maintained all test instrumentation. Contractor support was provided by BHTI for engineering support, design of aerodynamic modifications (ref 5, app A), and design and installation of SCAS modifications (ref 6). Aviators from 268th Attack Helicopter Battalion, 9th Infantry Division, provided user comments during operational testing. Additional user pilots were obtained from the 7th Infantry Division and from the U.S. Army Aviation Board. Flight restrictions contained in the operator's manual (ref 4) and the airworthiness release (ref 7) were observed. The helicopter was evaluated against the requirements of military specification MIL-H-8501A (ref 8). Testing was conducted in accordance with the test plan (ref 9) in the configurations listed in table 1 and at the conditions shown in table 2.

TEST METHODOLOGY

6. Flight testing was conducted in three phases: an IMC flight evaluation of the standard configuration AH-1F, evaluation of authorized configuration changes, and a limited operational user evaluation. The purpose of the first phase was to quantitatively evaluate the handling qualities using standard test techniques and data reduction procedures described in appendix D and reference 10, appendix A, and to qualitatively evaluate the handling qualities characteristics while performing simulated IMC flight tasks. The purpose of the second phase was to similarly evaluate various authorized aircraft configuration and procedural changes which attempted to correct deficiencies and shortcomings identified during phase 1. The configurations to be evaluated were identified and prioritized at a meeting attended by AVSCOM, BHTI, and AEFA representatives, held at Headquarters, AVSCOM, St. Louis, Missouri, on 10 January 1985. The purpose of the third phase was to obtain an operational evaluation of the aircraft's handling qualities during simulated IMC flight in the configuration determined from the results of phase 2. Performance standards associated with the simulated IMC flight tasks are those contained in the Aircrew Training Manual (ref 11). A Handling Qualities Rating Scale (HQRS) (fig. D-1, app D) was used to augment pilot comments relative to handling qualities and performance of instrument flight tasks. Flight parameters were recorded using cockpit instrumentation and an inflight magnetic tape recorder. Parameters which were considered critical were monitored in real time using telemetry. The data parameters are presented in appendix C. Pilot comments were recorded by hand and by voice tape recorder during each flight.

Table 1. Test Configurations

Symbol	Configuration[1]
BL	Standard AH-1F configuration (baseline); two TOW[2] missile launchers four dummy missiles on each outboard station, one 19-tube rocket launcher on each inboard station
ADS	Baseline, modified by additional pitot-static source provided through Air Data Subsystem
CYC	Baseline, modified by reduction of cyclic friction and/or cyclic centering spring preloads
FLAP	Baseline[3], modified by addition of a Gurney flap
FIN	Baseline[3] modified by removal of 90-degree gearbox fairings and addition of a ventral fin
GAIN	Baseline[3], modified by changes in pitch and roll SCAS[4] gains, and addition of attitude hold capability in pitch and roll channels
HOLD	Baseline[3,5], modified by addition of attitude hold capability in pitch and roll channels

NOTES:

[1]Various modifications of communication/navigation avionics cockpit arrangements were integrated with other configuration changes.
[2]TOW: Tube-launched, optically, tracked, wire command link.
[3]Reduced cyclic friction and reduced cyclic centering spring preloads.
[4]SCAS: Stability and Control Augmentation System.
[5]One flight conducted in clean (no wing stores) external configuration.

Table 2. Test Conditions

Test	Configuration	Average Gross Weight (in.)	Average Center of Gravity (in.)	Average Density Altitude (ft)	Average Calibrated Airspeed (kt)
Control System Mechanical Characteristics[1]	BL	N/A	N/A	N/A	N/A
	CYC	N/A	N/A	N/A	N/A
Control Positions In Trimmed Forward Flight	BL	9590	198.6	6220	43 - 127
	ADS	9340	198.8	6160	65 - 115
	FLAP	9160	200.1	5630	53 - 124
	FIN	9780	199.4	6310	53 -120
	GAIN	9820	199.4	6310	53 - 120
Static Longitudinal Stability	BL	9660	198.6	5000	95 - 136
	CYC	9510	199.1	5000	99 - 131
	HOLD	9820	199.4	5020	103 - 129
Static Lateral-Directional Stability	BL	9340	199.4	5840	87, 106, 116
	CYC	9310	199.2	6150	87, 106, 116
	FLAP	9370	199.8	5230	116
	FIN	9510	199.1	4730	87, 114
	HOLD	9430	199.4	4780	116
Dynamic Stability	BL	9530	198.5	5410	69, 104, 116
	FLAP	9260	200.1	6460	116
	FIN	9530	199.1	4940	87, 114
	GAIN	9310	199.4	5880	106
	HOLD	9360	199.4	5210	115
Simulated SCAS[2] Failures	BL	9390	198.5	5470	49 - 115
	FLAP	8960	200.0	6350	117
	HOLD	9300	199.4	5500	101, 116
Simulated Engine Failure	BL	9450	198.5	5810	67, 103
	FLAP	9030	200.0	6350	107
	HOLD	9120	199.4	5520	102, 115
Instrument Takeoffs	BL	9780	198.8	3020	0 - 70
	ADS	9550	199.1	2700	0 - 70
	CYC	9860	199.4	2860	0 - 70
	FIN	9520	199.1	2800	0 - 70
	GAIN	9690	199.4	1930	0 - 70
	HOLD[3]	8840	194.7	2860	0 - 70
Basic Instrument Flight	BL	9520	198.7	5110	71, 105, 116
	ADS	9420	199.1	5000	85, 108, 115
	CYC	9460	198.9	4670	75, 100, 116
	FLAP	9480	199.7	6500	74, 100, 115
	FIN	9440	199.1	4700	100, 114
	GAIN	9060	199.4	6840	100, 115
	HOLD	9420	199.5	4080	101, 116
Holding Patterns	BL	9610	198.7	6100	104
	CYC	9470	199.4	5780	100
	FIN	9590	199.1	5500	100
	GAIN	9160	199.4	6860	101
	HOLD	9290	199.5	6660	100
	HOLD[3]	8520	194.7	5780	99
Instrument Approaches	BL	9370	198.7	4220	103
	ADS	9420	199.1	4000	108
	CYC	9440	199.1	4240	103
	FLAP	9450	199.8	4500	100
	FIN	9560	199.1	4000	100
	GAIN	9520	199.1	4510	102
	HOLD	9160	199.5	4270	102
	HOLD[3]	8330	194.7	4060	103

NOTES:

[1]Conducted with engine and rotors static, external electrical and hydraulic power applied.
[2]SCAS: Stability and Control Augmentation System.
[3]No external wing stores.

RESULTS AND DISCUSSION

GENERAL

7. An IMC flight evaluation of the AH-1F helicopter was conducted which included implementation of configuration and procedural changes in an attempt to qualify the aircraft for IMC flight. Four deficiencies and seven shortcomings were identified during phase 1, instrument flight evaluation of the standard AH-1F. During phase 2 testing, configuration modifications intended to correct the aircraft deficiencies were evaluated. These configuration changes included use of the air data system as a pitot-static source, flight control mechanical characteristics modifications, aerodynamic modifications, SCAS modifications, and cockpit avionics modifications. The recommended configuration for flight in IMC incorporated the following modifications: attitude hold capability in the pitch and roll axes, cyclic control friction adjusted to 1.0 pounds, cyclic centering spring preloads adjusted to 3.0 pounds, and very high frequency omnidirectional range (VOR) navigation and very high frequency (VHF) communication control panels installed at the copilot/gunner station. In this configuration, the test aircraft was flown in actual IMC and a user evaluation (phase 3) was conducted.

PHASE 1 - INSTRUMENT FLIGHT EVALUATION

General

8. A quantitative and qualitative evaluation of instrument flight characteristics of the AH-1F helicopter was conducted using the IMC qualification criteria established in Military Specification MIL-H-8501A (ref 8, app A). The AH-1F tested exhibited essentially the same deficiencies and shortcomings as the previously tested AH-1P and was unacceptable for flight in IMC. Four deficiencies were identified: the easily excited lateral gust response, the unsatisfactory location of avionics controls, the poor cyclic flight control system mechanical characteristics, and the large change in airspeed position error in climbs. Additionally, seven shortcomings were noted: the persistent lateral-directional oscillation, the weak static longitudinal stability at cruise airspeed, the engine/airframe incompatibility, the lateral trim changes with airspeed and power, the location of the Environmental Control System (ECS) control head and rain removal switch, the obstruction of the vertical reference mark on the attitude indicator, and the lack of storage space in the cockpit area.

Handling Qualities

Cyclic Control System Characteristics:

9. Cyclic control system characteristics were measured in a static condition, as described in appendix D. Prior to the test, a flight control rigging check was conducted and the cyclic friction (not adjustable by the pilot) was set per maintenance instructions (ref 13, app A). Control force as a function of control displacement is presented in figures E-1 through E-4 and summarized in table 3. Control system characteristics in flight were qualitatively evaluated and were the same as those observed under the static test conditions. Cyclic forces were approximately 50 percent greater for the side-arm controller located in the copilot/gunner station. The force discontinuity caused by the large breakout forces resulted in control position overshoots when the pilot was required to make

Table 3. Cyclic Control System Characteristics[1]

		Breakout Force (Incl. Friction) (lb)		Control Force Versus Position Gradient (lb/in)		Limit Control Force (lb)		Trim Control Displacement Band (in)
Control	Direction	Test Results	MIL-H-8501A Maximum (Deviation)[2]	Test Results	MIL-H-8501A Maximum	Test Results	MIL-H-8501A Maximum	Test Results
Longitudinal	Forward	2.5	1.5 (2.25)	1.9	2.9	13.0	8.0	1.2
	Aft	3.09				13.5		
Lateral	Left	2.5	1.5 (2.25)	1.5	2.0	11.5	7.0	1.0
	Right	3.0				12.0		

NOTES:

[1]Pilot station; foce trim ON; control forces measured at center of cyclic grip; cyclic friction and centering spring preloads set per maintenance instructions.
[2]Bell Helicopter Textron, Detail Specifiction No. 209-997-398A, 5 October 1979.

small cyclic movements in flight. The large trim control displacement bands of 1.2 inches longitudinally and 1.0 inches laterally eliminated the force cues which would normally assist the pilot returning to and maintaining trim conditions within the small control input band required for IMC flight. The large cyclic control forces and reduced cyclic control travels (requiring smaller and more precise inputs) at the copilot/gunner station were fatiguing. The combined effects of high longitudinal and lateral breakout forces, control force gradients, and large trim control displacement bands precluded the smooth cyclic control movements necessary for the precise aircraft attitude control required in IMC flight. The poor cyclic flight control system mechanical characteristics are a deficiency for IMC operation. The longitudinal and lateral breakout forces (including friction) and limit control forces exceed the limits specified in MIL-H-8501A.

Control Positions in Trimmed Forward Flight:

10. Control positions were determined in ball-centered forward level, climbing, and descending flight for the conditions listed in table 2. The test results are presented in figure E-5. Longitudinal control position variations with airspeed were essentially linear and displayed increasing forward control position with increasing airspeed. Lateral control position showed significant trim change with airspeed and power. A lateral control trim change of 0.3 inch occurred in level flight between 100 and 120 knots calibrated airspeed (KCAS), while longitudinally that airspeed change required 0.5 inch of control travel, resulting in an uncomfortable left forward movement of the cyclic at a 30 degree angle to the longitudinal axis of the aircraft. From level flight at 80 KCAS, a lateral control trim change of 0.6 inch to the left was required to initiate a 1000 feet per minute (fpm) climb, and 0.5 inch to the right to initiate a 1000 fpm descent. The lateral trim changes with airspeed and power are a shortcoming.

Static Longitudinal Stability:

11. The static longitudinal stability characteristics were evaluated in ball-centered level flight at the conditions specified in table 2. The test results are presented in figure E-6. The static longitudinal stability, as indicated by the variation of longitudinal cyclic control position versus airspeed, was positive (increasing forward longitudinal control required to trim at increased airspeed). The gradient, however, was shallow (approximately 0.008 inch/knot) indicating nearly neutral stability. Within the airspeed band of 20 knots faster and slower than the trim airspeed, the longitudinal cyclic control displacements remained within the trim control displacement band, and no repeatable force cues were present. This weak static longitudinal stability appeared neutral during IMC flight and, coupled with the poor cyclic control system characteristics, required moderate pilot compensation to maintain a trim cruise airspeed within +5 knots (HQRS 4). The weak static longitudinal stability at cruise airspeed is a shortcoming.

Static Lateral-Directional Stability:

12. The static lateral-directional stability characteristics were evaluated in level flight at the conditions specified in table 2. The test results are presented in figure E-7. Static directional stability was positive (increasing left directional control with increasing right

sideslip) throughout the sideslip envelope and is satisfactory. Dihedral effect was positive (increasing right lateral cyclic control with increasing right sideslip) throughout the sideslip envelope and is satisfactory. Sideforce cues (as indicated by bank angle variation with sideslip) were adequate, apparent at three degrees left or right sideslip from trim. The static lateral-directional characteristics are satisfactory.

Dynamic Stability:

13. The longitudinal and lateral-directional dynamic stability characteristics were evaluated in level, climbing, and descending flight at the conditions specified in table 2. Selected time histories are presented in figures E-8 through E-16.

14. The long-term response was oscillatory and undamped at all tested conditions with a period of approximately 36 seconds. Excitation of the long-term response was not apparent in IMC flight. The long-term dynamic characteristics are satisfactory.

15. The longitudinal short-term gust response was deadbeat in the pitch axis, but exhibited a residual coupled lateral-directional oscillation. This residual oscillation was also present following lateral control pulse inputs. The lateral-directional oscillation remained small in magnitude at a maximum rate of two degrees per second and was essentially undamped with an approximate period of three seconds and a roll-to-yaw ratio of 2:1. This response was bothersome during simulated IMC flight because of the ease of excitation and persistent nature. The existence of a persistent lateral-directional oscillation fails to meet the requirements of paragraph 3.6.1.2 of MIL-H-8501A, and is a shortcoming.

16. The principal lateral short-term response to a simulated gust was heavily damped; however, there was little tendency for the aircraft to return to the trimmed flight condition after the rates produced by the disturbance had subsided. The aircraft response following a lateral gust disturbance was nearly neutral, slowly convergent in the roll axis and slowly divergent in the yaw axis. This characteristic was very apparent during simulated IMC flight in other than smooth air. Inadvertent roll attitude excursions of up to 10 degrees in light turbulence were observed and required constant pilot corrective inputs. Straight and level flight at cruise conditions in light turbulence was difficult (HQRS 5) and maintaining wings level dominated the pilot's attention. When complicated with other tasks such as tuning radios, navigating, or flying an approach procedure, the necessary division of attention increased the difficulty dramatically (HQRS 6 and 7). The easily excited lateral gust response is a deficiency for IMC operation.

17. The directional short-term gust response exhibited significant roll-yaw coupling, was moderately damped, and is satisfactory. The aircraft exhibited a very slight adverse yaw characteristic, which is satisfactory. The spiral stability characteristics are mildly convergent, returning to level flight from a 10 degree bank in approximately 16 seconds, and are satisfactory.

Aircraft Systems Failure:

18. The aircraft response to a sudden simulated engine failure was evaluated in level, climbing, and descending flight at the conditions specified in table 2. A representative

time history is presented in figure E-17. A delay of two seconds following loss of power was unattainable at airspeeds greater than 100 KCAS. The characteristic left roll and yaw rates and rapid rotor decay, aggravated by high power settings, have been well documented during previous testing of the AH-1F and remained unchanged during this evaluation; however, no problem specifically associated with IMC flight was identified. The aircraft failed to meet the requirements of paragraph 3.5.5 of MIL-H-8501A in that aircraft reaction following a simulated engine failure at high torque settings precluded safe autorotational entry after a two-second control delay.

19. SCAS disengagements were evaluated in level, climbing, and descending flight at the conditions specified in table 2. A representative time history is presented in figure E-18. At airspeeds below 100 KCAS recoveries required little compensation to maintain roll and yaw attitudes within 3 degrees (HQRS 3). At airspeeds above 100 KCAS roll and yaw oscillations were divergent; however, at 120 KCAS a 15 second delay was possible, and recovery was controllable (HQRS 5). Aircraft reaction to SCAS disengagements at and below 120 KCAS is satisfactory.

Engine Torque Oscillation

20. A persistent engine torque oscillation was observed in level and climbing flight, easily excited during any power change. Torque oscillations occurred at approximately three cycles per second as shown in figure E-19. This persistent engine torque oscillation is an indication of engine/airframe incompatibility, and may contribute to the excitation of the lateral-directional oscillation discussed in paragraph 15. The engine/airframe incompatibility, as evidenced by the persistent engine torque oscillation, is a shortcoming.

Cockpit Evaluation

General:

21. The cockpit was qualitatively evaluated in conjunction with the instrument flight capability evaluation. The presence of test instrumentation and equipment was considered during the assessment. The suitability for IMC flight of the cockpit arrangement, comfort, normal procedures, and readibility of gages and notations was satisfactory except as discussed in the following paragraphs.

22. The one deficiency and three shortcomings that were identified during the AH-1P IMC evaluation are valid for the AH-1F helicopter. The shortcomings are the vertigo-inducing location of the ECS control head and rain removal switch, the obstruction of the vertical reference mark on the attitude indicator (pilot's), and the lack of storage space in the cockpit. The shortcomings do not preclude IMC flight. The deficiency is discussed below.

Avionics Controls Arrangement:

23. The control panels for the ultra high frequency (UHF), VHF, VOR, automatic direction finder (ADF), and transponder radios and the horizontal situation indicator (HSI) course select knob are located in the aft cockpit. The frequencies and course selections

must be frequently changed during instrument flight, but the copilot/gunner (CPG) cannot assist the pilot with these avionics controls. The pilot must operate the flight controls (fly the aircraft) and at the same time select new avionics settings. Aircrew training manual (ATM) flight limits are consequently often exceeded when the lateral gust response is encountered. The unsatisfactory location of the avionics controls remains a deficiency of the AH-1F for IMC flight in that the CPG cannot assist the pilot when a radio frequency, transponder code, or course selection change must be made on avionics controls used during IMC flight.

Pitot-Static System

Level Flight:

24. The ship's standard airspeed system was calibrated in level flight using the trailing bomb method. Data are presented in figure E-20. The ship's system indicated airspeed in level flight varied from 3 knots less than calibrated airspeed at 49 KCAS to 3 knots greater than calibrated airspeed at 112 KCAS. The ship's airspeed system error in level flight is satisfactory.

Climbs and Descents:

25. The ship's standard airspeed system was calibrated in climbs and descents using a trailing bomb and by comparison to the instrumented boom airspeed system. Data are presented in figure E-21. The ship's system indicated airspeed error in descents was essentially the same as the level flight error. The indicated airspeed error in climbs, however, increased significantly with rate of climb and application of power. The indicated airspeed in a 1500 fpm climb was 10 knots greater than calibrated airspeed at 86 KCAS.

26. A time history of a transition from climb to level flight is shown in figure E-22. With calibrated airspeed held constant at 86 KCAS, the indicated airspeed decreased from 94 to 84 knots (KIAS). In IMC flight the pilot will correct for this apparent 10-knot deceleration with a forward cyclic input, leading to a power adjustment to maintain altitude, which will cause another change in the indicated airspeed error. The large change in airspeed position error in climbs is a deficiency of the AH-1F for IMC flight.

Instrument Flight Capability

General:

27. Flight testing at the conditions specified in table 2 was conducted to qualitatively determine flight crew workload and evaluate flight characteristics while flying in simulated IMC in both smooth and turbulent atmospheric conditions. The pilot in the rear seat and the CPG in the front seat functioned as an integrated crew, and all flights were flown with either curtains installed in the aft cockpit or utilizing an instrument training hood. The ship's airspeed and altimeter systems were used for all simulated instrument flight tasks. Performance standards for pilot IMC tasks were in accordance with the ATM. The

AH-1F is not suitable for IMC flight due to excessively high pilot workload which precludes meeting ATM performance standards.

Instrument Takeoff:

28. Instrument takeoffs (ITO's) were conducted using the ATM procedure for zero-zero (ceiling-visibility) conditions. A representative time history is presented in figure E-23. Following the described procedure and maintaining a pitch attitude of one bar-width below the horizon on the pilot's attitude indicator resulted in a very slow acceleration. Approximately 30 seconds after the target power application was established, the ship airspeed indicator first became effective, a period during which precise aircraft attitudes were difficult to maintain. Target torque settings (10 to 15 percent above hover power) at the conditions tested were 95 to 100 percent. This high setting combined with the sensitivity of the torque to aircraft attitude changes and very small collective adjustments caused the pilot to pay an inordinate amount of attention to the torquemeter during his instrument cross-checks to prevent an overtorque condition, to the further detriment of attitude, heading, and airspeed control. With force trim OFF, the heading could not be maintained consistently within +10 degrees and pilot workload during the ITO was very high (HQRS 7). With force trim ON, improved force cues made attitude and heading control easier; however workload remained high (HQRS 6).

29. ITO's were also performed using the ATM procedure for 100(feet)-1/4(mile) conditions. A representative time history is presented in figure E-24. The ability to use outside visual references while establishing the power setting and accelerating to a readable airspeed allowed the pilot to avoid the initial attitude and heading control problems described above. Longitudinal cyclic control inputs and corresponding torque excursions were smaller. The transition to an instrument climb was made without difficulty. Adequate performance was attainable with significantly lower workload than that required by the zero-zero procedure (HQRS 5).

Climbs and Descents:

30. Instrument climbs and descents were initiated from trimmed level flight conditions at 80, 100, and 120 KIAS. Climb rates at 120 KIAS were inadequate (less than 500 feet per minute) due to an insufficient power margin. The large airspeed error in climbing flight described in paragraphs 25 and 26 caused the pilot considerable difficulty in establishing and maintaining a desired rate of climb. To establish a 1000 fpm climb from level flight at 100 KIAS, the initial power increment caused an increase in indicated airspeed of 5 to 10 knots. The pilot compensated for the increased airspeed with an aft cyclic input, resulting in an increased rate of climb of 200 to 300 fpm. The pilot then reduced power to adjust the rate of climb resulting in a decrease in indicated airspeed. Likewise adjusting power from a 1000+ fpm to a 500 fpm climb following an instrument takeoff resulted in 10 KIAS deviations and 300 fpm climb rate overshoots (HQRS 5). The tendency to chase airspeed and vertical speeds was aggravated by the magnitude and abruptness of the changes in climb/descent rates, and improved by a knowledge of appropriate power settings.

31. The large lateral cyclic control trim changes with power changes (para 10) combined with a large lateral trim control displacement band and high lateral breakout plus friction forces (para 9) were evident during instrument climbs and descents, and contributed to the high workload.

Straight and Level Flight:

32. Straight and level instrument flight was conducted at 80, 100, and 120 KIAS in smooth air and in light turbulence. Desired performance could be obtained in smooth air conditions; however, close pilot attention to the basic instrument cross-check was necessary to compensate for the absence of force cues both longitudinally and laterally near trim (HQRS 4). The small corrective cyclic inputs were always within the trim control displacement band. In light turbulence the pilot workload was considerably increased by the significant lateral gust response (para 17) and persistent lateral-directional oscillations (para 16). The pilot's full attention was required for the normal instrument cross-check, and any distraction caused an immediate roll attitude divergence (HQRS 6). The constant lateral cyclic corrections that were required to maintain wings level diverted attention from airspeed and heading deviations. Flight parameters at 100 and 120 KIAS varied by 10 knots, 10 degrees heading, 150 feet altitude, and 15 degrees bank.

Turns:

33. Instrument turns were conducted in both directions at standard rate and one-half standard rate in level flight, climbs, and descents. Maintaining a desired angle of bank ranged from easy (HQRS 3) in smooth air to difficult in light turbulence, requiring high pilot workload to contend with gust disturbances of up to 10 degrees of bank with no tendency to return to the desired bank angle (HQRS 6). In level turns in light turbulence, altitude variations of 150 feet and airspeed variations of 10 knots occurred in a 90 degree heading change. In climbing and descending turns, the indicated airspeed error induced by power changes (described in para 30) added to the pilot workload. Desired rollout headings could be acquired within 10 degrees.

Holding Patterns:

34. Holding patterns were flown in smooth air and light turbulence, both in a standard pattern over a nondirectional radio beacon (NDB) station and at an intersection of two VOR stations. During station holding, the only distraction to basic flying tasks were timing inbound/outbound legs and applying wind corrections; however, the procedure required close pilot attention to maintaining pitch and bank attitudes, particularly in turns, and resulted in altitude variations of 150 to 200 feet (HQRS 5). When complicated during intersection holding by the requirement to retune VOR stations and reset the course indicator on the HSI, adequate standards were not attainable, and variations of 15 degrees of bank and 20 degrees of heading were encountered (HQRS 6 and 7).

Instrument Approaches:

35. Published NDB, VOR, and instrument landing system (ILS) instrument approach procedures were flown in smooth air and light turbulence. In every case, adequate stan-

dards could be maintained and the approach completed in a safe manner only under a high pilot workload (HQRS 6). Avionics changes and reference to approach plates were major tasks in that the pilot could not divert his attention from primary aircraft flying tasks for more than two to three seconds at a time. During power changes to initiate descent, level off, or missed approach procedures, the airspeed error and required lateral cyclic and pedal trim changes considerably added to the pilot workload. It was critical that the crew was very familiar with the approach procedure being flown and that the air traffic handling did not complicate the procedure with late turns to final, additional radio handoffs, etc.

Unusual Attitude Recovery:

36. Recoveries from unusual attitudes were made in simulated instrument conditions. Approximately three to five seconds were required to regain control and an additional ten seconds to reestablish normal straight and level flight parameters. No significant difficulties were encountered; however, it was necessary for the pilot to be particularly aware of torque transients during the recovery to avoid an inadvertent overtorque condition (HQRS 4).

Typical IMC Profile:

37. A typical IMC profile flight was planned and flown in simulated instrument conditions in light turbulence. The flight was 1.7 hours in duration and included an instrument takeoff, radar vectoring, intercept and tracking on VOR radials, holding, and multiple instrument approaches. The CPG performed as an active crewmember and assisted the pilot in planning, making radio calls, copying clearances, navigating, and flying the aircraft (for short periods in straight and level flight only).

38. Any distraction from the pilot's immediate task of flying the aircraft presented a problem with roll attitude control. Because of the exclusive location of avionics control heads in the aft cockpit (para 23), the pilot was required to make all frequency changes. Presetting frequencies prior to flight was helpful, particularly for the transponder, which was difficult to change in flight. The absence of a clock and fuel gage in the front cockpit loaded the pilot with some navigational duties and level flight checks that distracted from attention to aircraft control.

39. Crew planning and cockpit coordination was extremely important and resulted in considerable intercom traffic. Navigation was almost exclusively accomplished from the front cockpit, although avionics settings and frequencies could not be observed or changed by the CPG. Similarly, assistance with radio calls by the front seat was difficult when frequencies could not be observed or changed. The problem of cockpit coordination was intensified during instrument approaches when use of the intercom could interfere with controller radio traffic. The lack of readily available storage space for navigation and approach publications was evident in both cockpits.

40. During all phases of the flight, the easily excited lateral gust response (para 16) caused problems. Making slow cyclic inputs helped the tendency to overcontrol in both

pitch and roll, and a knowledge of appropriate power settings and a conscious effort to not chase airspeed and vertical speed with power changes helped reduce the number and frequency of control inputs. Since the CPG was qualified and current in the AH-1F, he was able to give the pilot occasional short rest periods. Although the flight was not long and the crew was properly rested, the workload was such that at the end of the flight the pilot felt considerably fatigued and a second leg of flight of the same duration would not have been advisable.

PHASE 2 - EVALUATION OF CONFIGURATION CHANGES

General

41. A qualitative and quantitative evaluation of instrument flight characteristics of the AH-1F helicopter with specific modifications was conducted in an effort to verify correction of the deficiencies and shortcomings identified in phase 1. The modifications evaluated were: use of the air data system as a pitot-static source, reduction of cyclic control friction, reduction of cyclic centering spring preloads, addition of a Gurney flap to the vertical stabilizer, removal of the 90-degree gearbox fairings, addition of a ventral fin, changes in pitch and roll SCAS gains, addition of attitude holds in the pitch and roll axes, and changes in cockpit avionics configurations. A configuration of the AH-1F was identified for which no deficiencies existed which would preclude flight in IMC. The modifications implemented were: reduced cyclic control friction, reduced cyclic centering spring preloads, addition of modified SCAS sensor amplifier modules which incorporated attitude hold features in pitch and roll, addition of a VOR navigation set with control panel in the front cockpit, and installation of the VHF communications radio control panel in the front cockpit. This configuration was acceptable for flight in simulated and actual IMC, and is recommended for incorporation prior to qualification of the AH-1F for IMC flight. It is also recommended that for IMC flight an instrument-current copilot who is qualified in the aircraft series be required, that the maximum airspeed be 100 KIAS, that instrument takeoffs be limited to conditions of no worse than 100 foot ceiling and 1/4 mile visibility, that a note be added to the operator's manual calling attention to the indicated airspeed discrepancy in climbs, and that the attitude hold system include a momentary interrupt and recentering feature.

Air Data Subsystem Pitot-Static Source

42. The Air Data Subsystem (ADS) was modified so that the ADS sensor head provided a pitot-static source for a cockpit airspeed indicator, as described in appendix B. The ADS indicated airspeed was calibrated using the instrumented boom for comparison in level flight from 60 to 120 KCAS, and in climbs and descents at 80 and 100 KCAS. The ADS indicated airspeed system was also qualitatively evaluated during ITO maneuvers. Data are presented in figure E-25. In level flight, the ADS indicated airspeed was three to five knots above calibrated airspeed. Unlike the ship's standard pitot-static system, there was no significant error introduced with power changes or vertical rates in climbs and descents. The ADS indicated airspeed was inaccurate and misleading to the pilot at transition airspeeds below 50 KCAS, however. During the ITO acceleration, the ADS indicated airspeed would initially fluctuate from 0 to 20 KIAS, then rapidly jump to 50

KIAS as the aircraft reached effective translational lift, and maintain that reading through the maneuver until the aircraft had accelerated through approximately 50 KCAS. This seemingly valid airspeed indication caused pilot consternation as indicated airspeed did not respond to longitudinal cyclic inputs. The ADS pitot-static source modification corrected the deficiency described in paragraph 26; however, it is not recommended for incorporation for IMC flight due to the discrepant indications at transition airspeeds during ITO's.

43. Further modifications to the aircraft pitot-static system in an effort to correct the deficiency described in paragraph 26 were not attempted. The following note should be included in the operator's manual:

> In transition from level to climbing flight at constant calibrated airspeed, an increase of more than ten knots indicated airspeed may be experienced; likewise, a decrease in indicated airspeed may be experienced during a level-off from a climb.

Flight Control Mechanical Characteristics Modifications

General:

44. Modifications to the flight control mechanical characteristics were performed. Flight control mechanical characteristics, static longitudinal stability, and IMC tasks were evaluated after each modification.

Cyclic Friction Reduction:

45. The preset cyclic friction was reduced from 2.0 ±0.25 pounds to 1.0 pound. A slight qualitative improvement in flying qualities was noted during IMC tasks. A small reduction in breakout forces (including friction) resulted in less problem with overcontrolling while making small cyclic movements.

Cyclic Centering Spring Preload Reduction:

46. The lateral and longitudinal cyclic centering spring preloads were reduced from 6.0 ±0.5 pounds to 3.0 pounds. While force gradients were effectively reduced and more linear near trim, the force discontinuity between the still relatively high breakout forces and lower force gradients near trim was emphasized, causing larger control overshoots when making small cyclic movements. A larger trim control displacement band continued to eliminate cyclic force cues near the trim position. Flying qualities were slightly degraded.

Cyclic Friction and Centering Spring Preload Reduction:

47. The cyclic friction reduction and centering spring preload reduction described in the preceding paragraphs were evaluated in combination. Data are presented in table 4 and

Table 4. Modified Cyclic Control System Characteristics[1]

Control	Direction	Breakout Force (Incl. Friction) (lb)		Control Force Versus Position Gradient (lb/in)		Limit Control Force (lb)		Trim Control Displacement Band (in)
		Test Results	MIL-H-8501A Maximum (Deviation)[2]	Test Results	MIL-H-8501A Maximum	Test Results	MIL-H-8501A Maximum	Test Results
Longitudinal	Forward	1.5	1.5 (2.25)	1.7	2.0	12.0	8.0	2.4
	Aft	2.5				13.0		
Lateral	Left	2.0	1.5 (2.25)	1.4	2.0	12.5	7.0	2.3
	Right	2.5				11.0		

NOTES:

[1]Pilot station; foce trim ON; control forces measured at center of cyclic grip; cyclic friction reduced to 1.1 lbs (±0.1); cyclic center centering spring preloads reduced to 3.0 lb.
[2]Bell Helicopter Textron, Detail Specifiction No. 209-997-398A, 5 October 1979.

figures E-26 through E-29. Cyclic breakout forces including friction were reduced, force gradients and limit control forces were reduced, and the trim control displacement bands were increased. Force gradients were more linear near trim with average values essentially unchanged. No SCAS feedback was noted during flight in moderate turbulence. Small precise control inputs were easier to perform at both the pilot and CPG stations when compared to the standard AH-1F because of reduced forces required and reduction of force discontinuities. Force cues near the trim position continued to be a problem due to the large trim control displacement bands; however, there was no degradation of handling qualities noted with the band increases. This configuration represented the greatest improvement over the standard AH-1F flight control mechanical characteristics. The combination of reduced cyclic friction and reduced cyclic centering spring preload corrected the deficiency described in paragraph 9 and is recommended for incorporation for IMC flight.

Aerodynamic Modifications

Addition of Gurney Flap:

48. The Gurney flap modification was installed on the trailing edge of the cambered vertical fin, as described in appendix B. Control positions in trimmed flight, static longitudinal stability, static lateral-directional stability, dynamic stability, simulated engine failures, simulated SCAS failures, and IMC tasks were evaluated with the Gurney flap installed at the conditions presented in table 2. Data are presented in figure E-30 through E-32. Lateral trim change with airspeed was aggravated, as evidenced by a 0.5 inch left cyclic migration as airspeed was increased from 100 to 120 KCAS. Slightly more pedal displacement from trim was required to maintain extreme sideslip angles during static lateral-directional stability tests. Otherwise, no change from the standard AH-1F flying qualities was noted during quantitative or qualitiative testing with the Gurney flap installed. The Gurney flap modification did not correct the deficiency described in paragraph 16 and is not recommended for incorporation for IMC flight.

Removal of 90-degree Gearbox Fairings:

49. The 90-degree gearbox fairings were removed, as described in appendix B, in order to reduce the effective dihedral and improve the lateral gust response. Control positions in trimmed flight, static lateral-directional stability, dynamic lateral-directional stability, and IMC tasks were evaluated in this configuration at the conditions presented in table 2. No changes from the standard AH-1F flying qualities were noted during either quantitative or qualitative testing. Removal of the 90-degree gearbox fairings did not correct the deficiency described in paragraph 16 and is not recommended for incorporation for IMC flight.

Addition of Ventral Fin:

50. The ventral fin modification was installed under the aft portion of the tailboom (as described in app B) with the 90-degree gearbox fairings removed in a further effort to

improve the lateral gust response of the aircraft. Control positions in trimmed flight, static lateral-directional stability, dynamic lateral-directional stability, and IMC tasks were evaluated in this configuration at the conditions presented in table 2. Data are presented in figures E-33 through E-35. Lateral trim change with airspeed was aggravated, as evidenced by a 0.5 inch left cyclic migration as airspeed was increased from 100 to 120 KCAS. Slightly more pedal displacement from trim was required to maintain extreme sideslip angles. No other changes from the standard AH-1F flying qualities were noted during testing in this configuration. No qualitative change in flying qualities was noted during performance of IMC tasks. The ventral fin modification did not correct the deficiency described in paragraph 16 and is not recommended for incorporation for IMC flight.

Stability and Control Augmentation System Modifications

General:

51. Modifications to the aircraft SCAS were implemented and evaluated. In each SCAS configuration, the same simulated IMC procedures were flown at similar conditions for comparison of handling qualities and pilot workload. The data are presented in table 5.

Changes in Pitch and Roll Gains:

52. Gain changes in the pitch and roll SCAS channels were implemented by modification of the appropriate SCAS amplifier modules as described in appendix B. The pitch SCAS gain was reduced as a function of actuator position, intended to improve maneuvering stability, and the roll SCAS channel was modified such that control quickening in the roll axis was reduced, intended to improve lateral controllability. Control positions in trimmed flight, maneuvering stability, dynamic stability, control response, simulated engine failures, and IMC tasks were evaluated at the conditions presented in table 2. A representative time history is presented in figure E-36. Although the small persistent lateral-directional oscillation described as a shortcoming in paragraph 16 was corrected, there was no improvement in the deficient lateral gust response (para 16). No improvement in IMC handling qualities was recognized during qualitative evaluation of IMC tasks in light turbulence.

Modified Gains with Pitch and Roll Attitude Holds:

53. Attitude hold features in the pitch and roll axes were installed as described in appendix B, and the SCAS gain changes described in paragraph 52 were maintained. The channels could be individually selected and the system was evaluated with the roll attitude hold only selected and with both attitude holds selected. Operational checks and drift error, control positions in trimmed flight, static stability, dynamic stability, control response, simulated engine failures, simulated SCAS failures, and IMC tasks were evaluated at the conditions specified in table 2. All tests were conducted with the reduced cyclic friction and force gradient preload described in paragraph 47. A representative time

Table 5. Handling Qualities Ratings During Performance of Instrument Tasks

Configuration	Task: Level Flight: Smooth	Task: Level Flight: Lt Turb	Task: Holding Pattern	Task: Non-Precision Aproach	Task: Precision Approach
Production SCAS[1] Gains	4	5.5	5	6	6
Modified SCAS Gains	4	5.5	5	6	6
Modified SCAS Gains with Roll Attitude Hold	4	5	4.5	5	5
Modified SCAS Gains with Roll and Pitch Attitude Holds	4	4	4	4	4
Production SCAS Gains with Roll and Pitch Attitude Holds	3	3	4	4	4

NOTE:

[1]SCAS: Stability and Control Augmentation System.

history is presented in figure E-37. With the pitch attitude hold engaged, no long-term response could be excited. Lateral control displacements to effect a desired angle of bank were approximately 50 percent greater. When the aircraft was disturbed in the lateral axis with the roll attitude hold engaged, it returned to level flight with a damped oscillatory response. The aircraft was flown in smooth air at a trim airspeed of 120 KIAS with controls free for a fifteen minute period. Resultant drift variations were +9 and -6 knots airspeed, pitch attitudes of ±2 degrees, and roll attitudes of level to 2 degrees right bank.

54. The IMC tasks which were evaluated and compared to the standard AH-1F were straight and level flight, instrument holding, NDB approaches, and ILS approaches, in smooth air and light turbulence. An appreciable reduction in pilot workload was immediately evident in all modes of flight due to the elimination of the tendency to diverge in roll attitude (lateral gust response). Handling qualities were consistently improved by one HQRS level with the roll attitude hold engaged, and showed further improvement with the pitch attitude hold also engaged. All tasks were flown within adequate standards when both attitude holds were engaged.

Production Gains with Pitch and Roll Attitude Holds:

55. The same attitude hold features described in paragraph 52 were evaluated with SCAS gains reestablished at standard AH-1F values. Trimmed flight control positions, static stability, dynamic stability, control response, simulated engine failures, SCAS disengagements, and IMC tasks were evaluated under the conditions specified in table 2. All tests were conducted with the reduced cyclic friction and force gradient preloads described in paragraph 47. Data are presented in figures E-38 through E-42. Qualitative results were the same as described in paragraphs 53 and 54. The addition of pitch and roll attitude holds corrected the deficiency described in paragraph 16 and is recommended for incorporation for IMC flight.

56. A representative time history of simulated engine failure with attitude holds engaged is presented in figure E-42. Aircraft response was similar to that described in paragraph 19. Delay times were essentially the same; however, the acceleration of the left roll at high power settings was greater by approximately 50 percent. When entry airspeed was reduced from 120 to 100 KIAS, attainable delay times to simulated engine failures increased from 1 to 2 seconds, and resulting left roll rates reduced from 22 to 12 degrees per second. A maximum airspeed of 100 KIAS is recommended for IMC flight.

57. The location of the attitude hold engage switches in the tested configuration was inconvenient to the pilot in that to select a new trim attitude the collective had to be released and the engage switches cycled. Consequently, the pilot selected only a straight and level condition at cruise airspeed and utilized force trim against the stick pressure when necessary. An attitude hold select switch(s) on the cyclic stick or collective, or in conjunction with force trim selection, would be desirable. For IMC flight it is recommended that the attitude hold system include a momentary interrupt and re-centering feature.

Human Factors

Avionics Control Panels for Copilot/Gunner:

58. A VHF/FM communications radio control head, AN/ARC-186(V), and a VOR navigation set control head, AN/ARN-123, were installed on the CPG instrument panel as described in appendix B. A VHF/VOR Take Control Panel installed on both the pilot's and CPG's instrument panels was used to determine and select controllability of the radios. During simulated IMC flight, the CPG was able to handle virtually all of the communications responsibilities and a significant portion of the navigational responsibilities. His greatly increased participation as an integrated crewmember corresponded to a decrease in the workload of the pilot, who was able to avoid much division of attention from basic instrument flight tasks. The installation of VHF/FM communications and VOR navigation control panels for the CPG corrected the deficiency described in paragraph 23 and is recommended for incorporation for IMC flight.

Course Deviation Indicator for Copilot/Gunner:

59. A Course Deviation Indicator (CDI), ID-1347, was installed on the CPG instrument panel as described in appendix B. The CDI display was slaved to the pilot's HSI, and as such the CPG was unable to select a desired course for the pilot. The CDI was somewhat beneficial in that it assisted the copilot in navigational orientation and assistance to the pilot, particularly during a precision approach; however, the mismatch of course selector indicators (not slaved between instruments) was often confusing. The addition of a CDI for the CPG is not recommended for incorporation for IMC flight.

IMC Profile with Recommended Modifications

60. Typical IMC profile flights were planned and flown in simulated instrument conditions (two flights) and in actual instrument conditions (three flights) in a configuration which incorporated the following recommended modifications: attitude hold capability in the pitch and roll axes, reduced cyclic control friction and centering spring preloads, and VOR navigation and VHF communication capability in the front cockpit.Flight in actual IMC totalled 2.6 hours and included instrument takeoffs, holding, and ADF, VOR, and ILS approaches. The CPG assisted the pilot in planning, making radio calls, copying clearances, navigating, and flying the aircraft for short periods. Actual IMC flight with CPG control of the VHF and VOR radios was evaluated as well as with pilot control of these radios.

61. The flights in simulated IMC were flown in smooth to light turbulent conditions, and handling qualities during conduct of specific tasks were the same as had been previously evaluated (table 5). Actual IMC flights were flown in smooth air, and pilot compensation during approaches and holding (frequency of cyclic inputs) was consistently less (HQRS 3). The pilot was able to effectively tune all radios when required. Although this distracted him from the primary task of flying for several seconds, desired flight performance

was maintained without instrument cross-checks by "trusting" the attitude hold system and not making any cyclic inputs. Likewise, reference to charts and publications was accomplished without degradation of flight performance.

62. The ability of the CPG to control communication and navigational radios was desirable in that the pilot workload was reduced and the CPG was able to perform as an effective crewmember to a greater capacity. Intercom transmissions were significantly reduced as the CPG could copy or look up frequencies, set radios, and make calls without pilot coordination.

63. Despite the described advantages and reduced pilot workload with the attitude hold features, it was desirable for the CPG to occasionally fly the aircraft, such as while the pilot adjusted his publications. Because of the uniqueness of flying with a side-arm cyclic control stick and the fact that the pilot was unable to directly observe the front seat occupant, it is recommended that an instrument-current copilot who is qualified in the aircraft series be required for IMC flight.

64. Instrument takeoffs were conducted using both the zero-zero procedure and the 100-1/4 procedure in simulated IMC flight; however, in actual IMC flight, only the 100-1/4 procedure was used. Actual weather conditions during instrument takeoffs were as low as 200 feet and 1 1/2 miles (ceiling and visibility). In these conditions using the 100-1/4 procedure, the aircraft was accelerated to and stabilized at climb airspeed (and power setting) and the pilot had completed his transition to instruments well prior to climbing through 100 feet. Using visual references during the critical initial power and attitude changes made the maneuver much more manageable than previously conducted in simulated IMC (HQRS 4), and there was no problem with fixation on high torque settings. It is recommended that, for IMC flight, instrument takeoffs be limited to conditions of no worse than 100 foot ceiling and 1/4 mile bility.

PHASE 3 - USER EVALUATION

65. A limited operational user evaluation was conducted to confirm the aircraft's capability to safely perform IMC flight when configured with the recommended modifications (as described in para 61). A brief evaluation of the standard (unmodified) AH-1F was conducted with the same user pilots concurrently for comparison. All flights were flown in day visual meteorological conditions (VMC) using the IMC curtains to simulate instrument conditions, and with a project pilot in the front seat performing full copilot duties. The mission profiles flown included instrument takeoffs, basic instrument flight and radio navigation, instrument holding, precision and non-precision instrument approaches, and recoveries from unusual attitudes. Participating pilots represented both the U.S. Army Forces Command and the U.S. Army Training Command. A profile of the individual user pilot qualifications is provided in table 6.

66. The cyclic control mechanical characteristics modifications (reduced cyclic friction and centering spring preloads) prompted no criticism from user pilots, and cyclic forces were generally considered to be not significantly lighter than in aircraft in current operational units. The avionics modifications (VOR and VHF control heads for the CPG) received unanimous approval, regarded as an enhancing characteristic. The attitude hold

Table 6. User Pilot Qualifications

User Pilot # (Name)	Total Time	AH-1 Time	Actual IMC Time	Special Qualifications
1 (Segundo)	220	35	0	
2 (Haberlin)	580	400	0	
3 (Disbrow)	1850	1650	0	SIP[1]
4 (Wonderly)	3100	800	47	IP[2], IFE[3]
5 (Metzger)	4300	3000	13	SIP
6 (Sanders)	4600	3100	35	SIP, IFE
7 (Splichal)	4700	2200	12	SIP
8 (Lyle)	4800	1500	118	IP

NOTES:

[1]SIP: Standardization instructor pilot.
[2]IP: Instructor pilot.
[3]IFE: Instrument flight examiner.

modifications evoked differing opinions and comments. All users agreed that the attitude hold feature made it much easier to accomplish IMC cockpit tasks such as tuning radios, referring to publications, etc., that the likelihood of the pilot allowing the aircraft to diverge to an unusual attitude was greatly reduced, and recoveries from unusual attitudes were relatively easy. Criticism of the attitude hold feature was directed toward a discomfort with relatively large cyclic displacements required to make small corrections and the lateral displacement of the cyclic required in a steady turn (as in a holding pattern). Those user pilots with the most AH-1 flight time were the most critical, and in some cases were able to maintain better performance standards without the attitude holds engaged. This was not the case with the less experienced pilots, who demonstrated a marked improvement in performance. Cyclic displacements during attitude/heading corrections and in steady turns would not be a problem if the system included a momentary interrupt and recentering feature as described in paragraph 57. Contributing factors to poorer performance by some experienced AH-1 user pilots were comparatively little experience in instrument flight and a reluctance to utilize force trim.

CONCLUSIONS

GENERAL

67. The AH-1F is unacceptable for flight in IMC.

68. The AH-1F is acceptable for flight in IMC when the following modifications are incorporated:

a. Attitude hold capability in the pitch and roll axes.

b. Cyclic control friction adjusted to 1.0 pounds.

c. Cyclic centering spring preloads adjusted to 3.0 pounds.

69. The suitability of the AH-1F for flight in IMC is enhanced when the following modifications are incorporated:

a. Installation of the VOR navigation set with control panel in the front cockpit.

b. Installation of a VHF/FM communications radio with control panel in the front cockpit.

DEFICIENCIES

70. The following deficiencies associated with flying the AH-1F in IMC were identified:

a. The easily excited lateral gust response (para 16).

b. The unsatisfactory location of avionics controls (para 23).

c. The poor cyclic flight control system mechanical characteristics (para 9).

d. The large change in airspeed position error in climbs (para 26).

71. The deficiencies identified in paragraphs 70a, b, and c are corrected when the aircraft is modified as described in paragraphs 68 and 69.

SHORTCOMINGS

72. The following shortcomings associated with flying the AH-1F in IMC were identified:

a. The persistent lateral-directional oscillation (para 15).

b. The weak static longitudinal stability at cruise airspeed (para 11).

c. The engine/airframe incompatibility (para 20).

d. The lateral trim changes with airspeed and power (para 10).

e. The location of the ECS control head and rain removal switch (para 22).

f. The obstruction of the vertical reference mark on the attitude indicator (para 22).

g. The lack of storage space in the cockpit area (para 22).

73. The shortcomings identified in paragraphs 72b and d are corrected when the aircraft is modified as described in paragraph 68.

SPECIFICATION COMPLIANCE

74. Within the scope of this test, the AH-1F helicopter failed to meet the following requirements of military specification MIL-H-8501A:

a. Paragraph 3.2.6 - Longitudinal control full travel forces exceed the 8.0 lb limit by 5.0 lb (62 percent) (para 9).

b. Paragraph 3.2.7 - Longitudinal control breakout force (including friction) exceeded the 1.5 lb maximum by 1.5 lb (100 percent) (para 9).

c. Paragraph 3.3.12 - Lateral control full travel forces exceed the 7.0 lb limit by 5.0 lb (71 percent) (para 9).

d. Paragraph 3.3.13 - Lateral control breakout force (including friction) exceeded the 1.5 lb maximum by 1.5 lb (100 percent) (para 9).

e. Paragraph 3.5.5 - Aircraft reaction following a simulated engine failure at high torque settings precluded safe autorotational entry after a two-second control delay (para 18).

f. Paragraph 3.6.1.2 - The aircraft exhibited a persistent lateral-directional oscillation (para 15).

RECOMMENDATIONS

75. The following modifications should be incorporated prior to qualification of the AH-1F for IMC flight:

a. Attitude hold capability in the pitch and roll axes (para 55).

b. Cyclic control friction adjusted to 1.0 lb (para 47).

c. Cyclic centering spring preloads adjusted to 3.0 lb (para 47).

d. Addition of a VOR navigation set with control panel in the front cockpit (para 58).

e. Installation of a VHF/FM communications radio with control panel in the front cockpit (para 58).

76. An instrument-current copilot who is qualified in the aircraft series should be required for flight in IMC (para 63).

77. Instrument takeoffs should be limited to conditions of no worse than 100 foot ceiling and 1/4 mile visibility (para 64).

78. The maximum airspeed for flight in IMC should be 100 KIAS (para 56).

79. The following note should be included in the operator's manual (ref 4, app A) (para 43):

> In a transition from level to climbing flight at constant calibrated airspeed, an increase of more than ten knots indicated airspeed may be experienced; likewise, a decrease in indicated airspeed may be experienced during a level-off from a climb.

80. The attitude hold system should include a momentary interrupt and re-centering feature (para 57).

APPENDIX A. REFERENCES

1. Final Report, USAASTA Project No. 72-29, *Instrument Flight Evaluation AH-1G*, July 1975.

2. Final Report, AEFA Project No. 79-08, *AH-1S(PROD) Airworthiness and Flight Characteristics for Instrument Flight*, November 1980.

3. Letter, AVSCOM, AMSAV-ED, 13 July 1984, subject: AH-1F Instrument Meteorological Conditions (IMC) Flight Evaluation.

4. Technical Manual, TM 55-1520-236-10, *Operator's Manual, Army Model AH-1S (PROD) AH-1S (ECAS) AH-1S (Modernized Cobra) Helicopter*, 11 January 1980, with change 13 dated 1 December 1987.

5. Engineering Order, BHTI No. 209-AWA-1152, 2 September 1986, subject: Recommended Size, Shape, and Installation Instructions for Gurney Flap, Vertical Fin Tab, and Ventral Fin.

6. Engineering Order, BHTI No. 209-AWA-1153/1154, 15 September 1986, subject: SCAS Modifications to Incorporate IMC Test Configuration on AH-1F Ship S/N 69-16423.

7. Letter, AVSCOM, AMSAV-E, 2 May 1985, with revision 6 dated 7 April 1987, subject: Airworthiness Release for Instrument Meteorological Conditions (IMC) Flight Test of the JAH-1F Helicopter with Flight Control System and Airframe Modifications.

8. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities, General Requirements For*, 7 September 1961, amended 3 April 1962.

9. Test Plan, AEFA Project No. 84-16, *AH-1F Instrument Meteorological Conditions (IMC) Flight Evaluation*, August 1984.

10. Flight Test Manual, Naval Air Test Center, *FTM 105, Helicopter Stability and Control*, November 1983.

11. Aircrew Training Manual, *Attack Helicopter, AH-1 (FC 1-213)*, 30 September 1984.

12. Technical Manual, TM 55-1520-236-23-2, *Aviation Unit and Intermediate Maintenance Manual, Army Model AH-1S (PROD) AH-1S (ECAS) AH-1S (Modernized Cobra) Helicopters*, 8 May 1980, with change 10, 31 August 1987.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. In phase 1 of the evaluation, the basic AH-1F was evaluated for flight in instrument meteorological conditions (IMC). In phase 2, various modifications were made to the basic aircraft and evaluated. The following paragraphs describe the basic aircraft, followed by a description of subsequent modifications.

BASIC TEST AIRCRAFT

General

2. The AH-1F helicopter is a two-place, tandem seat, single-engine aerial weapons platform. The aircraft features a dual hydraulic system and a conventional positive mechanical type flight control system which incorporates force trim and a three-axis Stability and Control Augmentation System (SCAS). The electrical power supply system provides redundancy in both DC and AC power distribution. The fuselage (forward section) employs aluminum alloy skin and aluminum, titanium, and fiberglass honeycomb panel construction. Honeycomb deck panels and bulkheads attached to main beams produce a boxbeam structure. These beams make up the primary structure and provide support for the cockpit, skid-type landing gear, stub wings, engine, pylon assembly, fuel cells, and tailboom. The nose section incorporates a 20mm cannon mounted on a universal turret and a gyro stabilized telescopic sight unit. The tailboom is a tapered semi-monocoque structure and supports the cambered vertical stabilizer, tail skid, synchronized elevators, and tail rotor drive system. The AH-1F incorporates two fixed cantilever wings to provide support for wing store pylons. Each wing has a fixed inboard pylon and an articulated outboard pylon (pitch axis only). In addition to a conventional pitot-static system, the aircraft includes an Air Data Subsystem (ADS) with a swiveling pitot-static probe as an integral part of the armament system. Additional description of the AH-1F is contained in the operator's manual (ref 4, app a).

3. The test helicopter, serial number 69-16423, was a production AH-1F with the K747 main rotor blades installed. The basic wing stores configuration was with two tube-launched, optically-tracked, wire command link (TOW) launchers on each of the outboard wing stores stations and one 19-tube rocket launcher on each of the inboard wing stores stations. The universal weapons turret and 20mm gun were removed and replaced by a non-functioning turret and gun which simulated the weight and drag of the replaced system. The telescopic sight unit was removed and replaced with a nose fairing. The wire strike protection system was installed.

4. Removable curtains were installed in the aft cockpit during conduct of simulated IMC flight as shown in figure B-1. These curtains were fabricated using white muslin target cloth and were attached to the interior of the window frames on the pilot's door and the pilot's jettisonable (left) window, and to the canopy frame forward of the pilot station and above the instrument panel, using velcro strips The pilot's overhead window was obscured using a cardboard panel. The curtains were effective in emitting ambient light while obscuring the pilot's outside visual references without limiting peripheral vision.

Figure B–1. Test Aircraft

Power Plant

5. The T53-L-703 turboshaft engine is installed in the AH-1F helicopter. this engine employs a two-stage, axial-flow, free power turbine; a two-stage axial-flow turbine driving a five-stage axial and one-stage centrifugal compressor; variable inlet guide vanes; and an external annular combustor. A 3.2105:1 reduction gear located in the air inlet housing reduces power turbine speed to a nominal output shaft speed of 6604.3 rpm at 100 percent N2. Maximum uninstalled engine shaft horsepower (shp) is 1800 shp at a sea level standard day condition;however, installed in the aircraft, the engine is limited by the transmission to 1290 shp for 30 minutes at or below 100 knots indicated airspeed (KIAS) and to 1135 shp above 100 KIAS.

Flight Controls

6. The primary flight control systems are the main rotor collective, fore-and-aft cyclic, lateral cyclic, and tail rotor controls. Each of these is a system of mechanical linkage, assisted by hydraulic cylinders, connecting the pilot and gunner control sticks and pedals to those mechanisms which rotate with and directly control the main rotor and tail rotor (fig B-2). Complete controls are provided for both pilot and gunner (fig B-3 and B-4); however, the gunner's flight controls are designed for occasional or emergency use. The pilot and gunner collective sticks are located on the left side of the pilot and gunner seats, with an adjustable friction system provided for the pilot only. Because of the difference in length, the gunner's collective stick has a 1.1 to 1 ratio mechanical disadvantage. A conventional cyclic control stick is mounted through the floor in front of the pilot seat. The cyclic friction is preset at 1.75 to 2.25 pounds to prevent SCAS feedback, and is nonadjustable to the pilot. The gunner's cyclic stick is mounted on the gunner right side console and has a 2 to 1 ratio mechanical disadvantage (from the pilot's stick), and requires a greater force of 1.63 to 1 ratio for cyclic movement. A set of pedals is provided for both the pilot and gunner for pitch control of the tail rotor system.

Force Trim System

7. The force trim system consists of electrically operated mechanical brakes and force gradient assemblies designed to steady the cyclic control stick (in both axes) and pedals against movement of their own accord and to induce artificial control feel into the flight control system. The force trim system can be energized by the pilot only by the FORCE TRIM switch (fig B-3). Each magnetic brake assembly consists of a rotary shaft which can be mechanically actuated and an electrically actuated magnetic brake that will hold the rotary shaft at any point in its travel when actuated by a switch on the cyclic stick. Depressing the cyclic stick force trim switch will cause the magnetic brake and force gradient assemblies to be repositioned to correspond to the positions of the cyclic stick and pedals, thus providing trim. The force gradient assemblies perform stick centering and force trim functions. Each force gradient assembly is a link equipped with an internal spring which connects the magnetic brake arm to a lever or bellcrank in the flight control system. A preload of 5.5 to 6.5 pounds is set on the force gradient assembly internal spring.

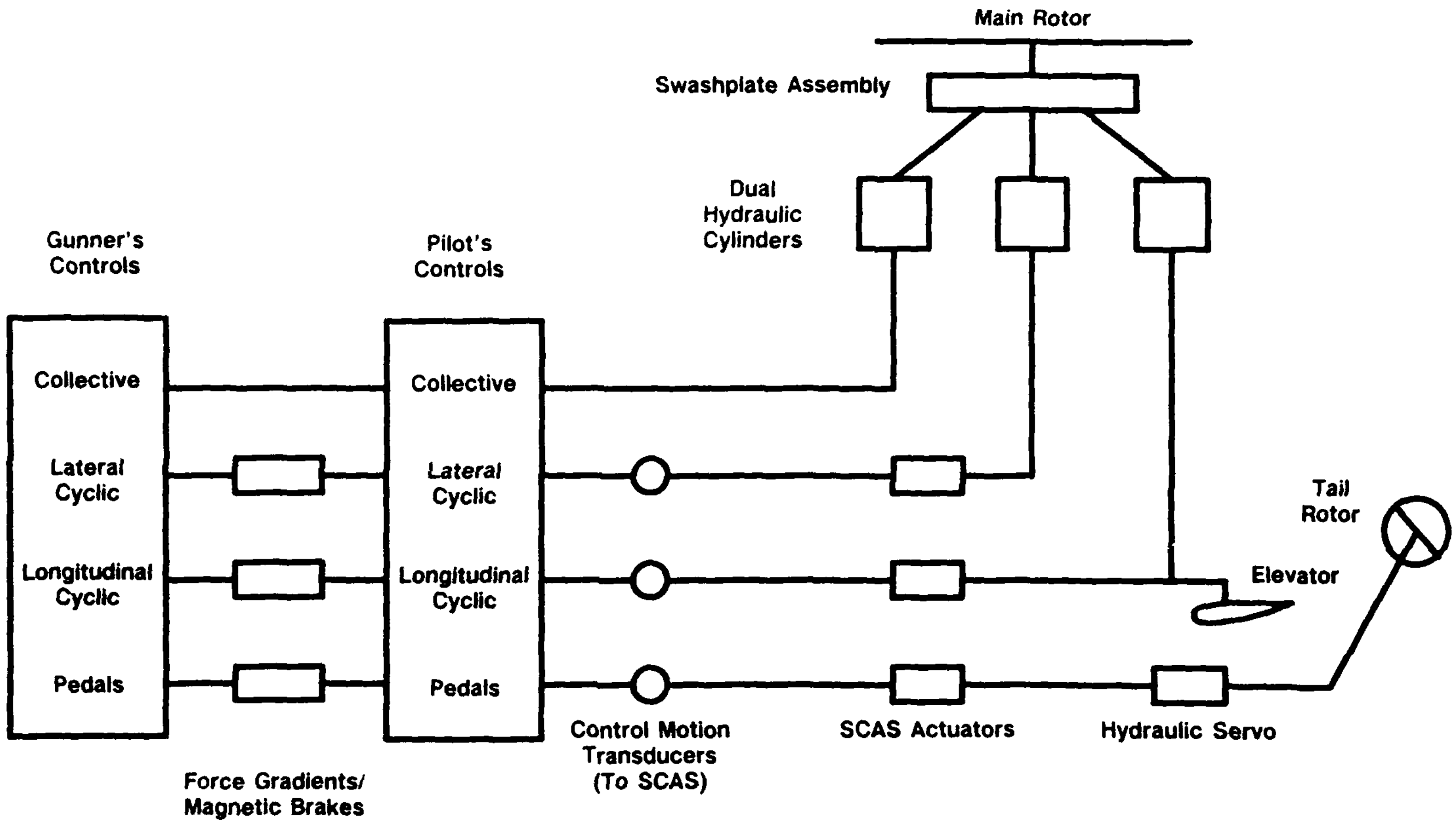


Figure B-2. Flight Control System Schematic

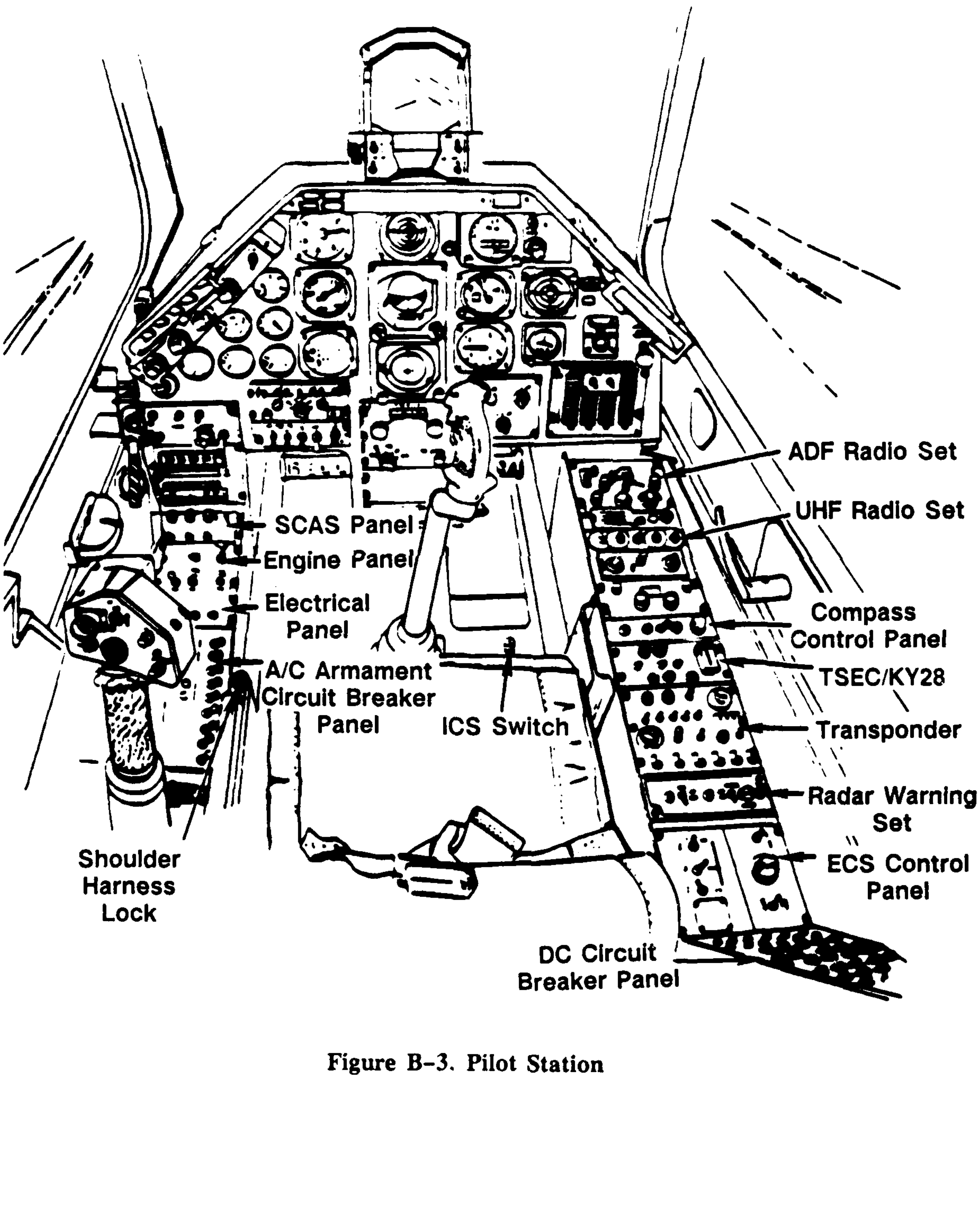


Figure B-3. Pilot Station

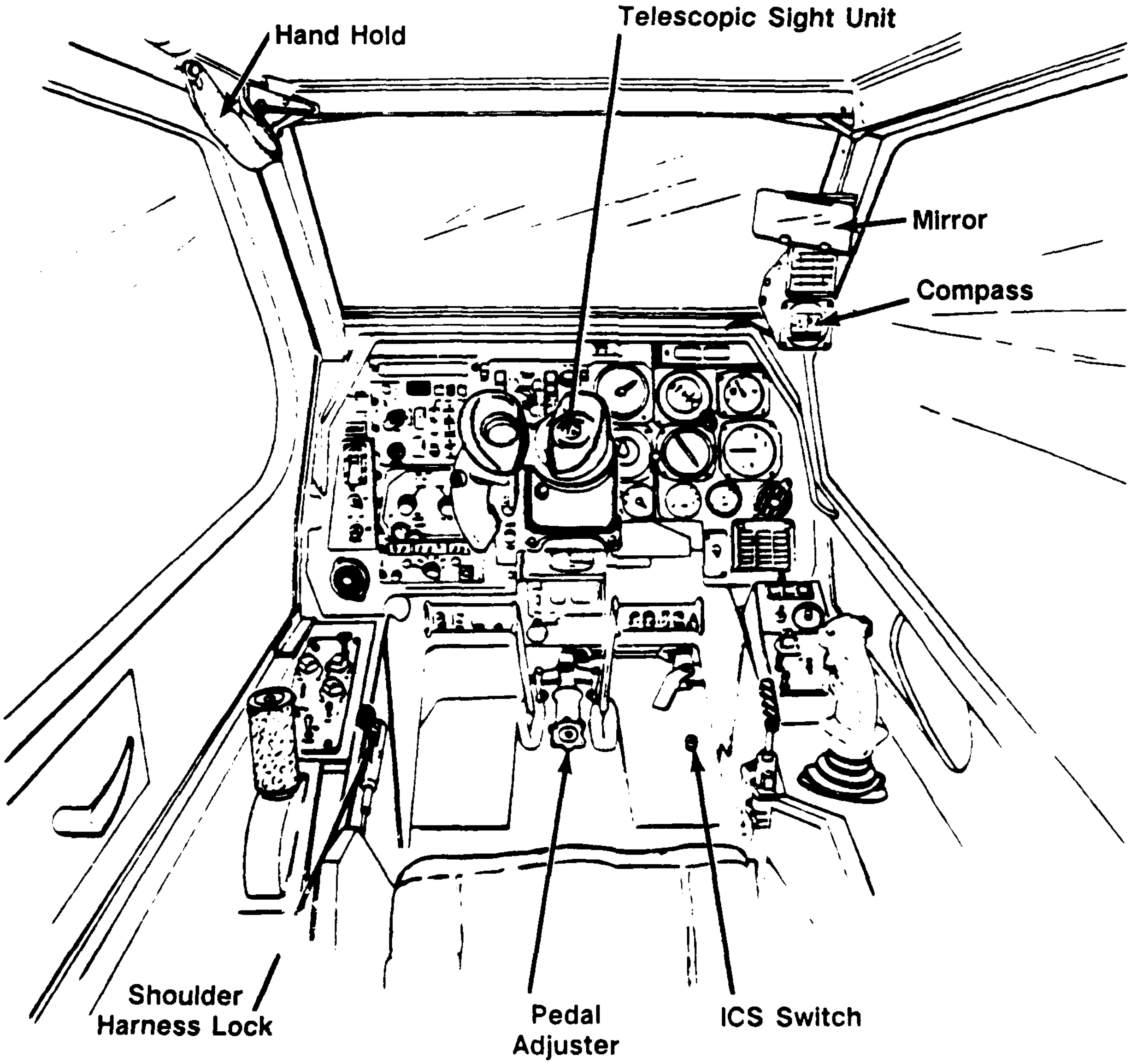


Figure B-4. Co-Pilot/Gunner Station

Stability and Control Augmentation System

8. The SCAS is a limited authority ($\pm$12.5% of total pilot control authority), three axis, rate damping system. The system is designed to cancel uncommanded helicopter rates by introducing electro-hydraulic inputs into the flight control system to augment pilot inputs (fig B-2). The directional SCAS servo actuator is powered by the number one hydraulic system and the longitudinal and lateral servo actuators are powered by the number two hydraulic system. A block diagram showing the functional relationship between individual SCAS components is presented in figure B-5. The SCAS is controlled through the SCAS control panel (fig B-6) located on the pilot left console, and the SCAS release switches on the pilot and copilot/gunner (CPG) cyclic control grips. The panel includes a power switch and three amber NO-GO lights, each associated with one of the SCAS channel (pitch, roll, and yaw) engagement switches. The NO-GO lights are illuminated when there is an unsatisfied command to the actuator and go out when the channel is ready for engagement. The SCAS pitch, roll, and yaw engage switches energize the appropriate channels of the SCAS and the electrical solenoid valves that control hydraulic pressure to the SCAS servo actuators. The cyclic grip SCAS release switches disengage all SCAS channels simultaneously and the channels must then be reengaged individually using the switches on the SCAS control panel. The sensor amplifier unit (fig B-7) is located behind the aft cockpit and contains three modules, one for each pitch, roll, and yaw channel. The sensor amplifier unit receives inputs from other components of the SCAS, sums, shapes, and amplifies the signals, then applies the output to the SCAS electro-hydraulic actuators.

9. The SCAS provides rate damping and control quickening (feed forward). Each channel of the SCAS consists of three functional loops: control (inner) loop, airframe (outer) loop, and pilot supplementary electrical (input) loop as shown in figure B-8. The control loop is designed to provide proportional control in that the electrical-hydraulic actuator displaces the main dual hydraulic cylinders a constant magnitude per unit input to the amplifier. SCAS actuator position information is fed back to the sensor amplifier modules via control transducers. The airframe loop is designed to provide attitude rate stabilization and airframe damping. The rate gyros in the three-axis rate sensor monitor and report to the sensor amplifier modules the actual angular rate of movement of the helicopter. The pilot loop provides pilot input to the inner loop through the use of control motion transducers, which are mechanically connected to the controls. These transducers are designed to electrically measure the movement of the controls due to pilot inputs and feed these pilot rate command signals forward to the appropriate sensor amplifier module. The sensor amplifier modules compare these signals with the airframe loop and inner loop inputs, then provide final signals to the electro-hydraulic actuators which extend or retract to adjust the aircraft rate to that commanded by the pilot.

Cockpit Instruments and Controls

10. Figures B-3 and B-9 show the location of instruments, switches, and panels for the pilot (rear) cockpit station in the standard configuration for the AH-1F. Figures B-4 and B-10 similarly describe the gunner (front) cockpit station. The normal avionics configuration includes UHF, VHF, and FM communications radios, an ADF navigation radio, doppler navigation equipment, a transponder, and a radar warning set.

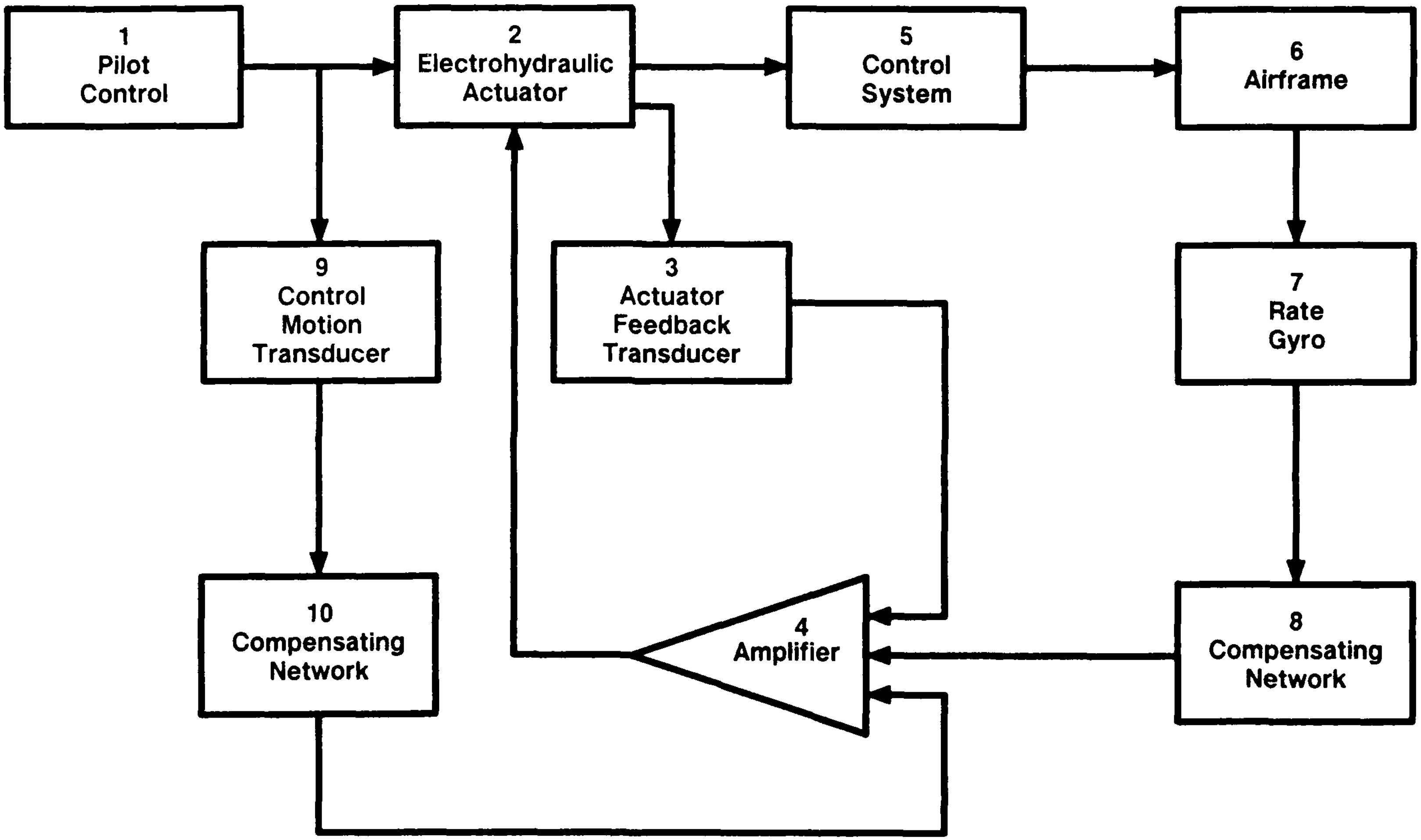


Figure B-5. SCAS Functional Block Diagram

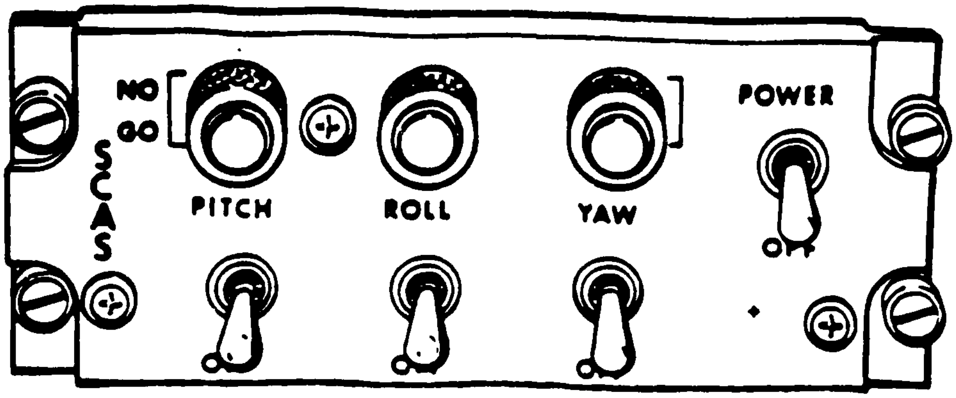


Figure B-6. SCAS Control Panel

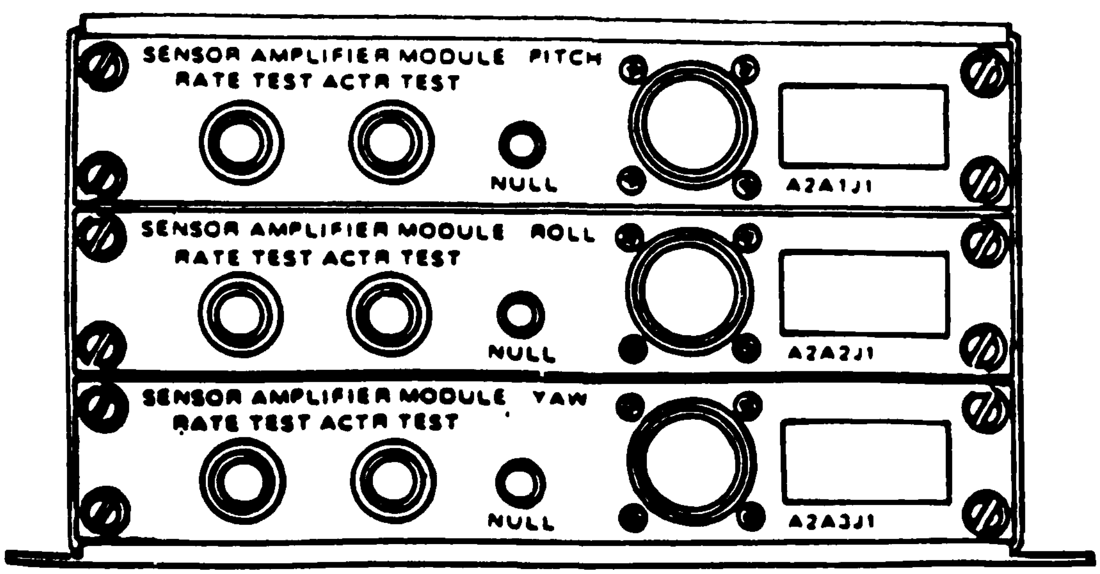


Figure B-7. SCAS Sensor Amplifier Unit

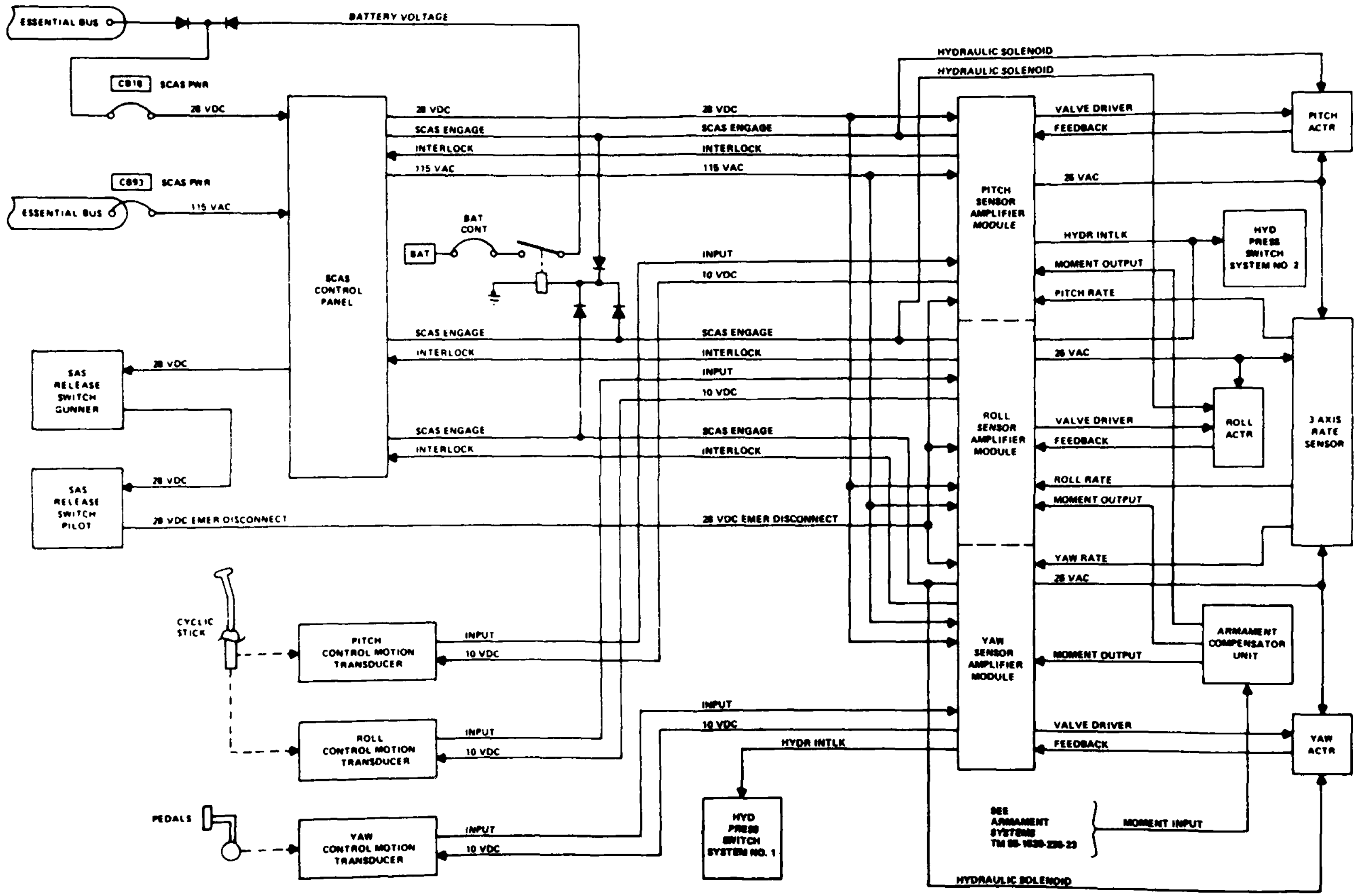


Figure B–8. SCAS Block Diagram

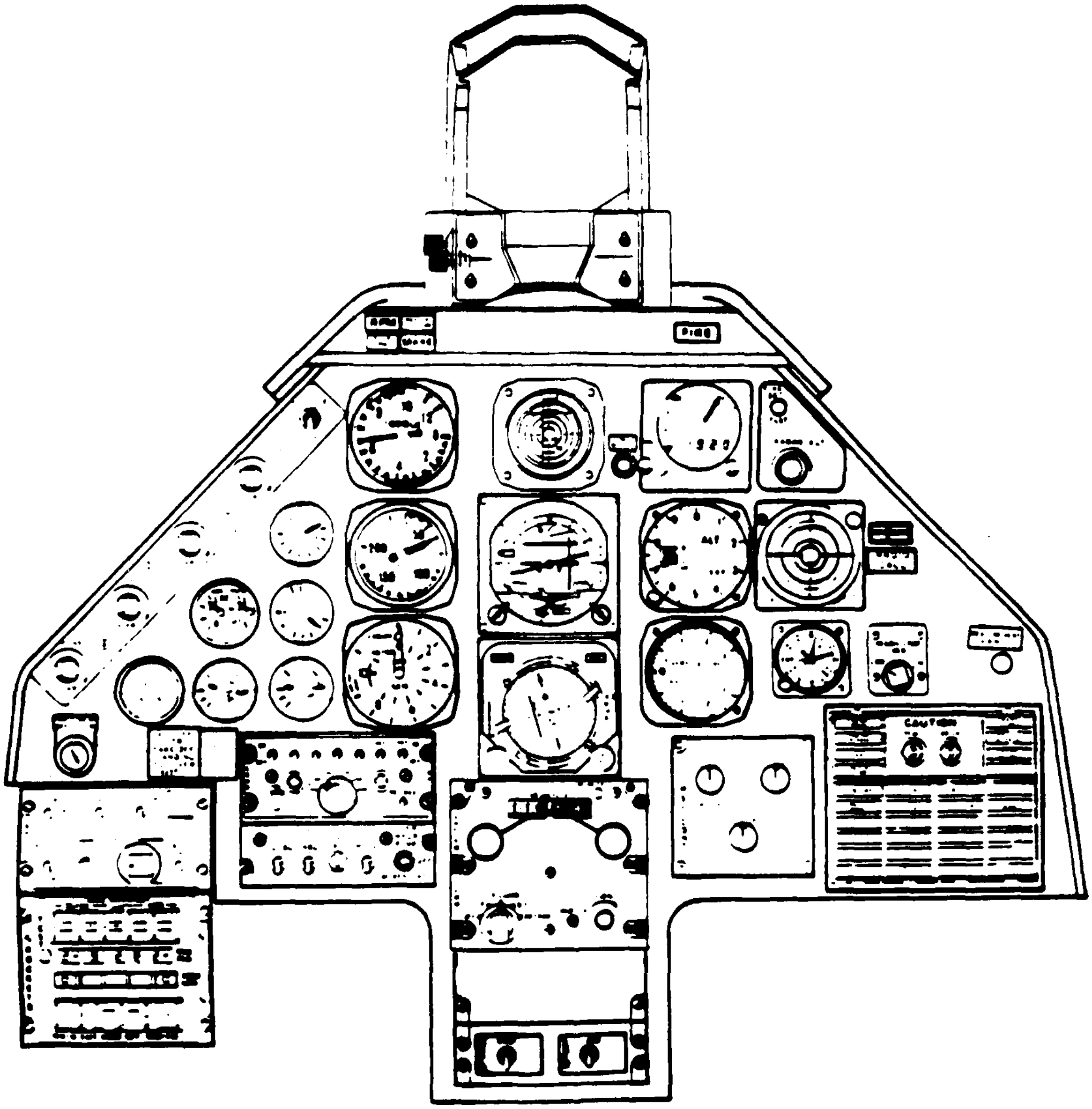


Figure B-9. Pilot Instrument and Control Panel

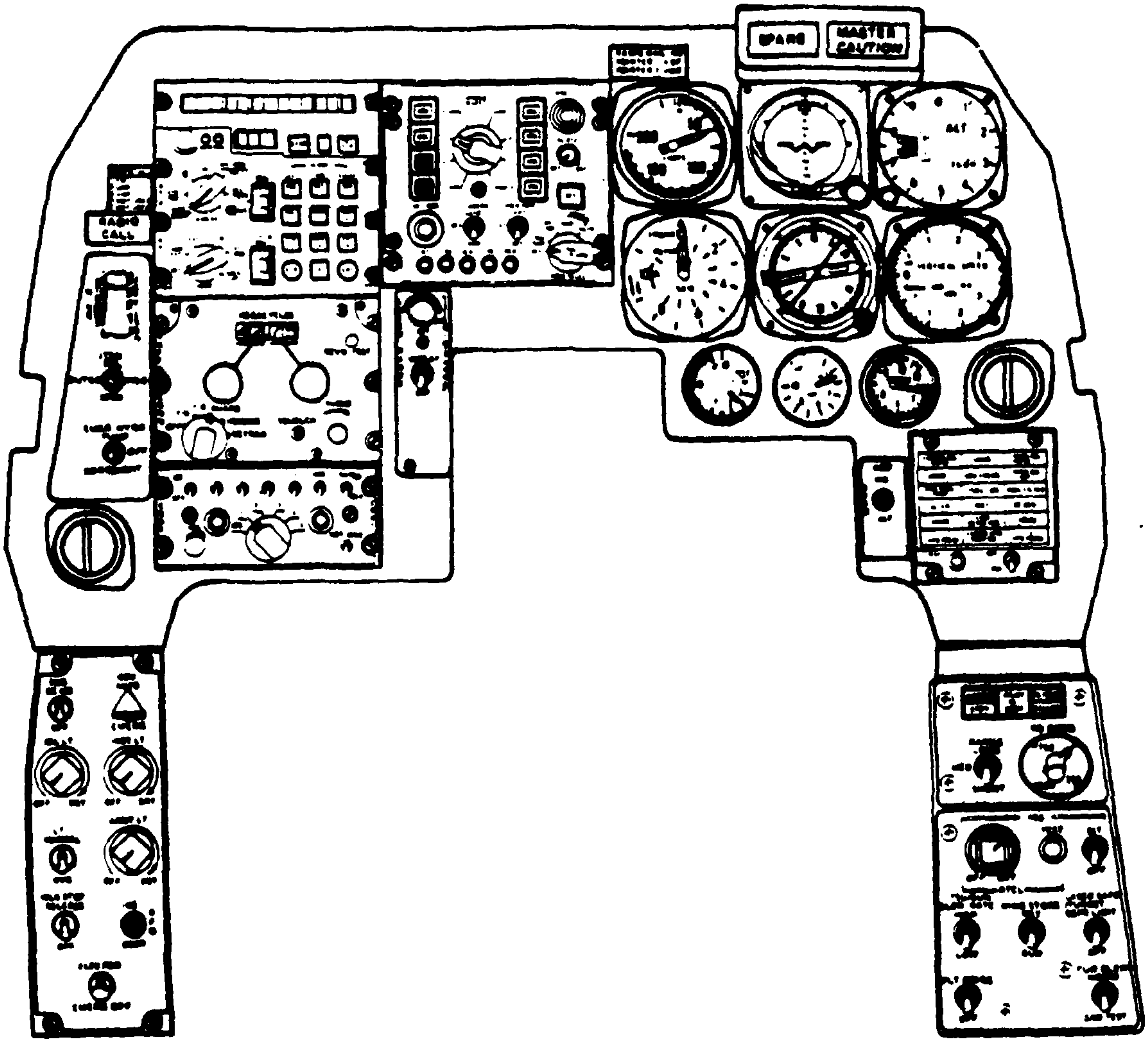


Figure B-10. Copilot/Gunner Instrument and Control Panel

11. The test helicopter, S/N 69-16423, was initially configured as shown in figures B-9 and B-10, with the following exceptions. The weapons sighting systems, armament control panels, doppler equipment, FM radio, and radar warning set were removed. A VOR radio set (AN/ARN-123) was installed. A test instrumentation control panel and necessary instrumentation gages and indicators were also installed.

Principle Dimensions

12. The principal dimensions and general data concerning the AH-1F helicopter are as follows:

Overall Dimensions:

Length, rotor turning	53 ft, 1 in.
Width, rotor turning	44 ft
Height, tail rotor turning	13 ft, 9 in.

Main Rotor (K747 IMRB):

Diameter	44 ft
Disc area	1520.53 ft2
Solidity	0.0625
Planform	Trapezoidal chord 30.0 in. tapering to 10.0 in. at tip
Blade twist	-0.556 deg/ft
Normal main rotor speed	324 rpm (100%)

Tail Rotor:

Diameter	8 ft, 6 in.
Disc area	56.75 ft2
Solidity	0.1436
Blade chord, constant	11.5 in.
Blade twist	0.0 deg/ft
Airfoil	NACA 0018 at the blade root changing linearly to a special cambered section at 8.27 percent of the tip
Normal tail rotor speed	1655.1 rpm (100%)

Fuselage:

Length, rotor removed	44 ft, 7 in.
Height	
to tip of tail fin	10 ft, 8 in.
to top of mast	12 ft, 3 in.
to top of transmission fairing	10 ft, 2 in.
Width	
fuselage only	3 ft
wing span	10 ft, 9 in.

skid gear tread	7 ft
Elevator	
span	6 ft, 11 in
airfoil	Inverted Clark Y
Vertical Fin	
area	18.5 ft2
airfoil	special cambered
height	5 ft, 6 in.
Wing	
incidence	17.0 deg
airfoil (root)	NACA 0030
airfoil (tip)	NACA 0024

MODIFICATIONS

Air Data Subsystem Pitot-Static System

13. The ADS installed on the AH-1F is designed to provide low airspeed information to the Fire Control Computer and to the pilot, and consists of three major components (shown in fig B-11): a swiveling probe Airspeed and Direction Sensor (AADS), an Electronics Processor Unit (EPU), and a Low Airspeed Indicator (LAI). In normal operation, the AADS samples local airflow pitot and static pressures, the pneumatic pressure outputs are fed to transducers in the EPU, and component airspeed outputs from the EPU are displayed on the LAI. In the modified test aircraft configuration, the LAI was removed and replaced with a sensitive airspeed indicator. The pneumatic pressure outputs to the EPU were disconnected, and pitot and static pressures were routed directly from the AADS to the airspeed indicator.

Gurney Flap

14. The Gurney flap modification to the test aircraft consisted of attachment of a fixed aluminum flap to the trailing edge of the cambered vertical fin, as shown in figure B-12. The flap had a span of 48 in, thickness of .071 in, and chord of 3.5 in, and was mounted such that 1.5 in chord extended to the right (tail rotor) side of the vertical fin. The Gurney flap was mounted to the fin by eight stainless steel brackets, four riveted to each side of the vertical fin.

Ventral Fin

15. The ventral fin modification to the test aircraft consisted of attachment of a fixed aluminum fin to the underside of the tailboom as shown in figure B-13. Design of the ventral fin was provided by contract with Bell Helicopter Textron, Inc. (BHTI). The fin had a total length of 81.7 in, thickness of .063 in, and a depth of 8.75 in. An L-shaped flange on the ventral fin was riveted directly to the center row of tailboom rivets, and

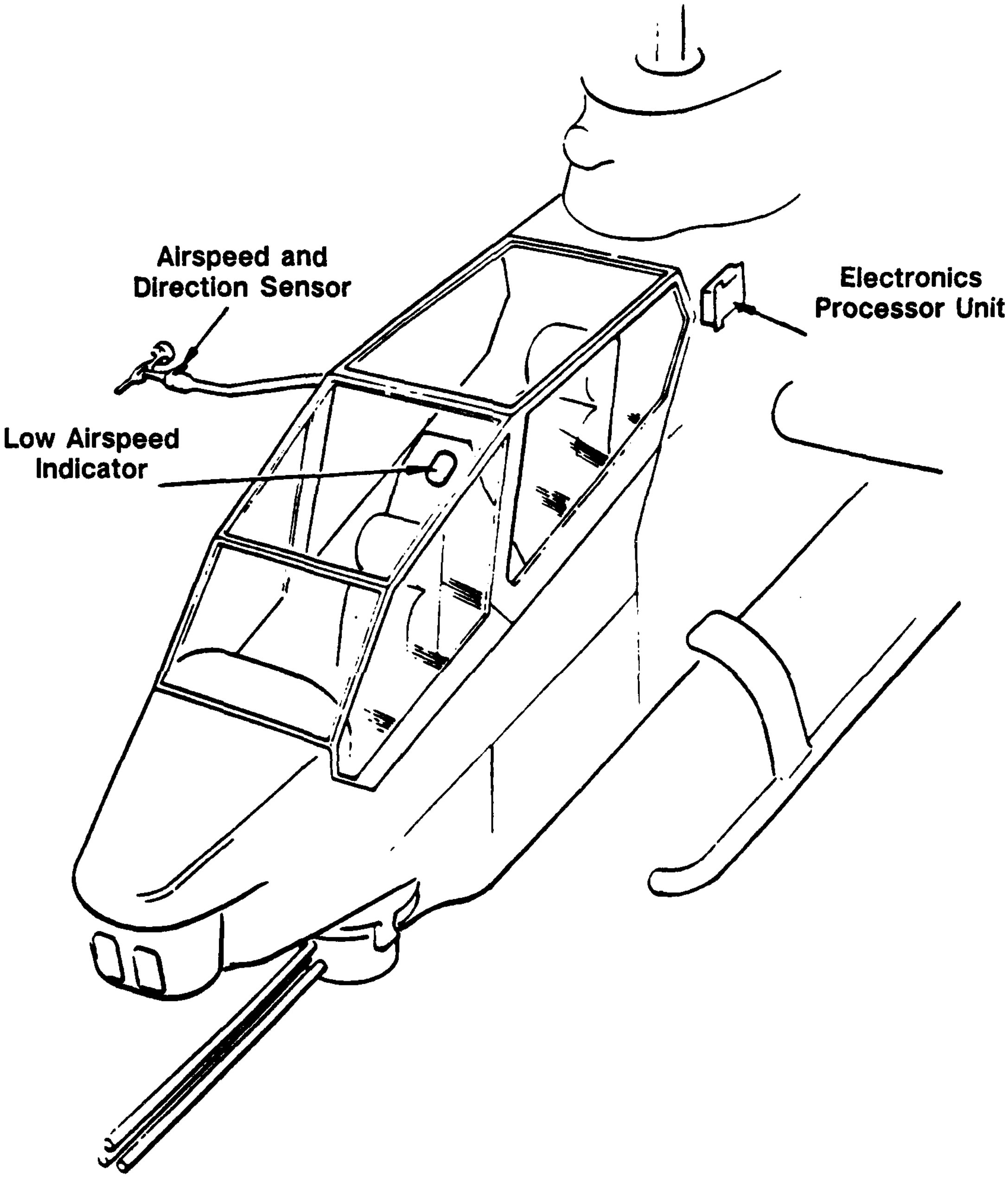


Figure B-11. Air Data Subsystem

Figure B-12. Gurney Flap

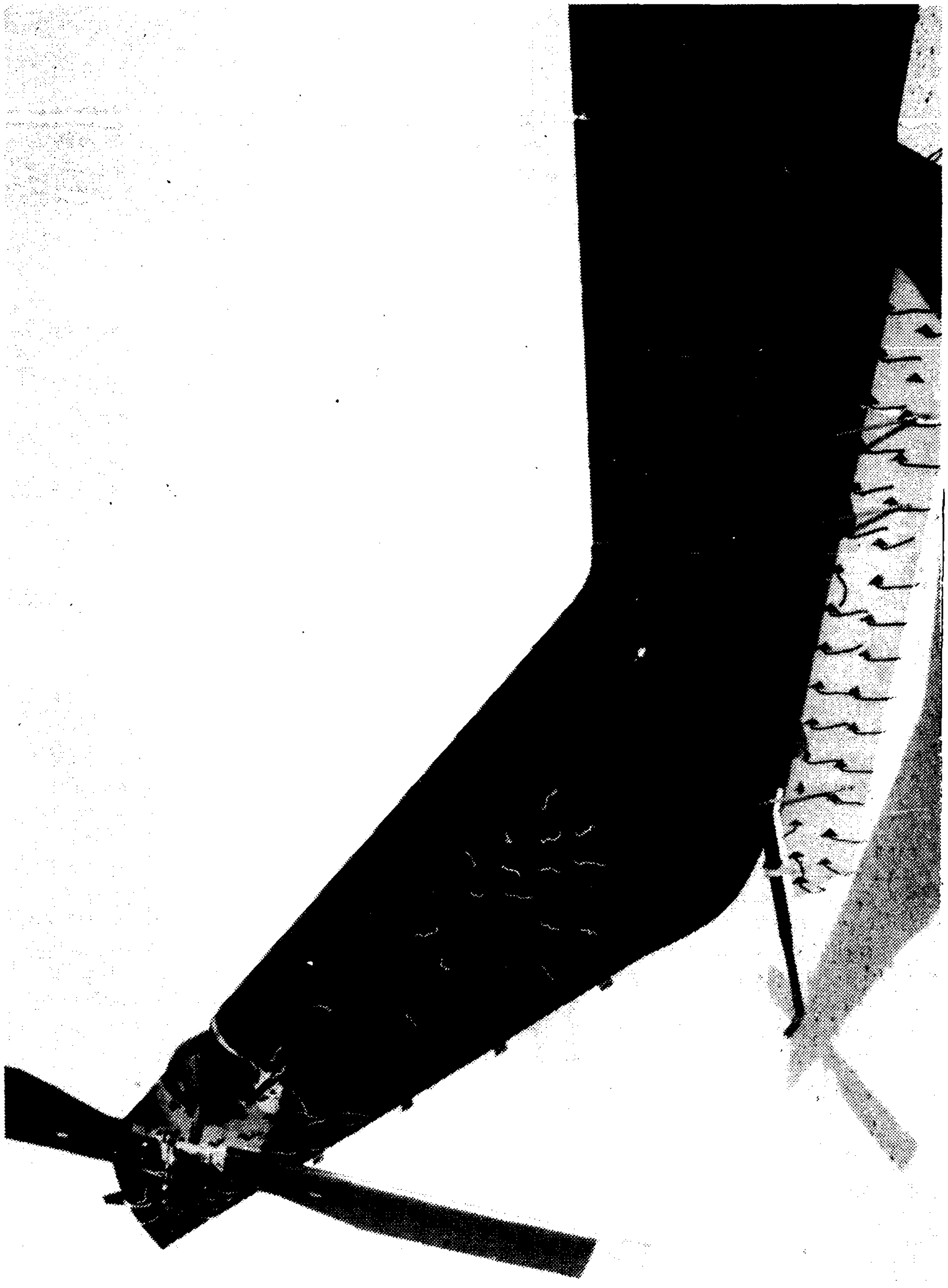


Figure B-13. Ventral Fin

support was provided by four aluminum tubular braces bolted to the tailboom on each side and a clamp attaching the trailing edge of the fin to the tail skid. Tufting was installed on the ventral fin and the cambered vertical fin for visual observation of the surface airflow.

Changes in Pitch and Roll SCAS Gains

16. The pitch and roll SCAS gain modifications to the test aircraft were effected by replacement of the production Pitch and Roll Sensor Amplifier Units (BHTI Part No. 209-074-081-115 and 209-074-081-117 respectively) with modified amplifiers provided by contract with BHTI. In the pitch channel, the overall SCAS gain was reduced as a function of actuator position. More precisely, the closed loop gain was decreased as a function of actuator displacement from the centered position, such that the SCAS was effective over a wider range of pitch rates before saturation occurred. In the roll channel, the SCAS control quickening feature was reduced by approximately 30 percent. The gain of the control motion amplifier was decreased while maintaining the same frequency response, resulting in a decrease in the overall gain of the feed forward loop.

Pitch and Roll Attitude Holds

17. The pitch and roll attitude hold modifications to the test aircraft were effected by replacement of the production Pitch and Roll Sensor Amplifier Units with modified amplifiers, installation of an attitude hold control panel, and modification of the ship's wiring to provide an input from the attitude gyro to the appropriate SCAS modules. The modified sensor amplifier units and the control panel were provided by contract with BHTI. The attitude hold control panel (figs B-14 and B-15) was installed on the lower left corner of the pilot's instrument panel. The pitch and roll hold engage switches were electrically energized switches such that they could not be engaged unless the corresponding SCAS channel was engaged. In addition, if the corresponding SCAS channel or the SCAS power was disengaged, or if the SCAS release button on the cyclic grip was depressed, the attitude hold function was disengaged. The system was designed such that the pilot could select either one or both of pitch and roll attitudes, with the aircraft attitude at the time the switch was engaged being the system's *trim* attitude. The attitude hold provided a continuous feedback loop from the ship's attitude gyro to input SCAS corrections for attitude deviation from the selected (trim) attitude. The system was limited in authority to 50 percent of the SCAS authority, or ±6.25 percent of total pilot control authority.

Copilot/Gunner Cockpit Configuration Changes

18. A VHF communications radio control panel, C-10604(V), and a VOR navigation set control panel, AN/ARN-123(V), and a Course Deviation Indicator (CDI), ID-1347, installed on the CPG instrument panel as shown in figure B-16. A VHF/VOR Take Control Panel (figure B-17) was installed on each of the pilot and CPG instrument panels. Indicator lights on each panel provided positive confirmation of radio control. The course deviation bar and glideslope deviation bar on the CDI were slaved to the

pilot's Horizontal Situation Indicator (HSI); however the course selection indicator was not slaved, and therefore did not indicate the course actually selected by the pilot. The course selector knob was not capable of selecting a desired course for the pilot's HSI.

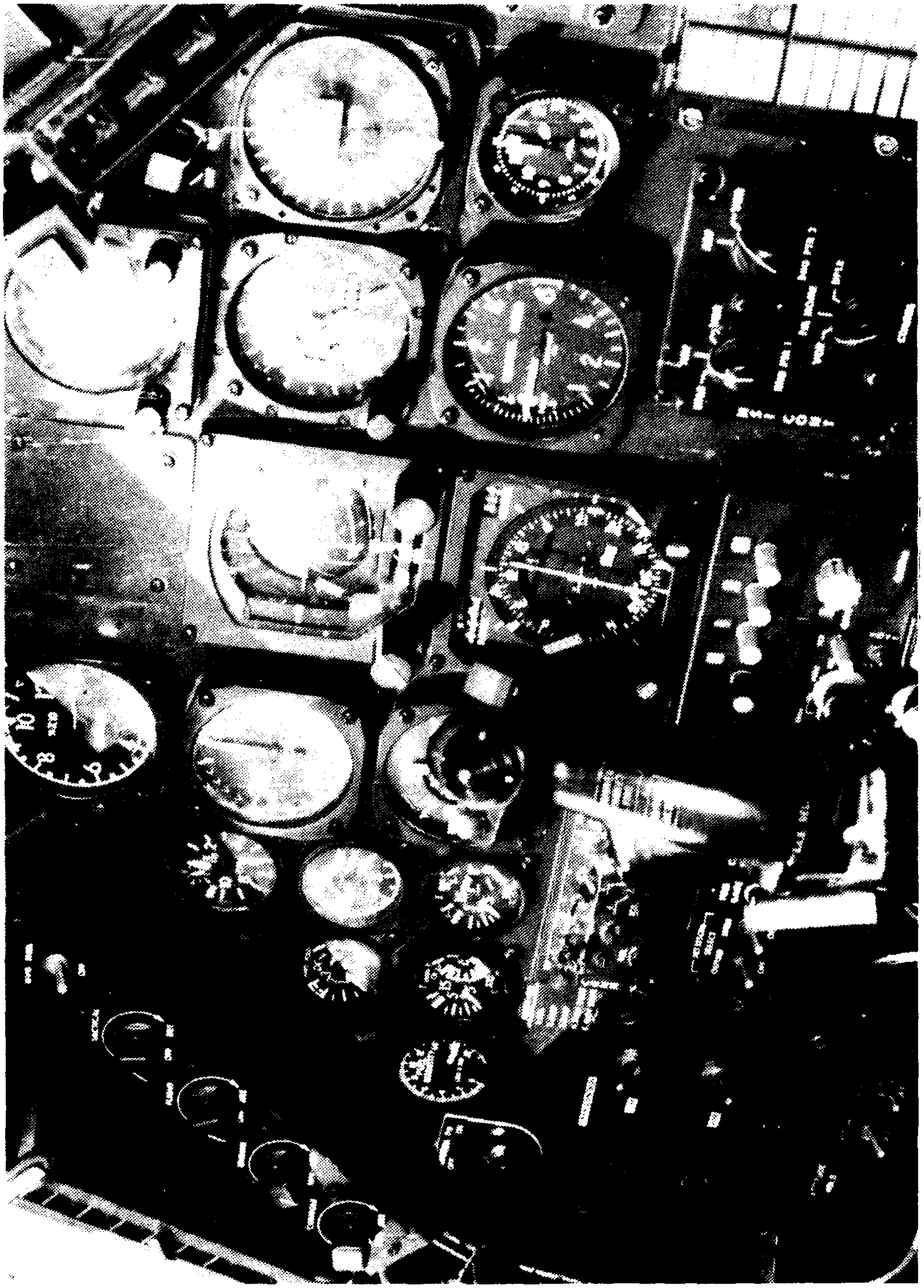


Figure B-14. Pilot's Instrument Panel

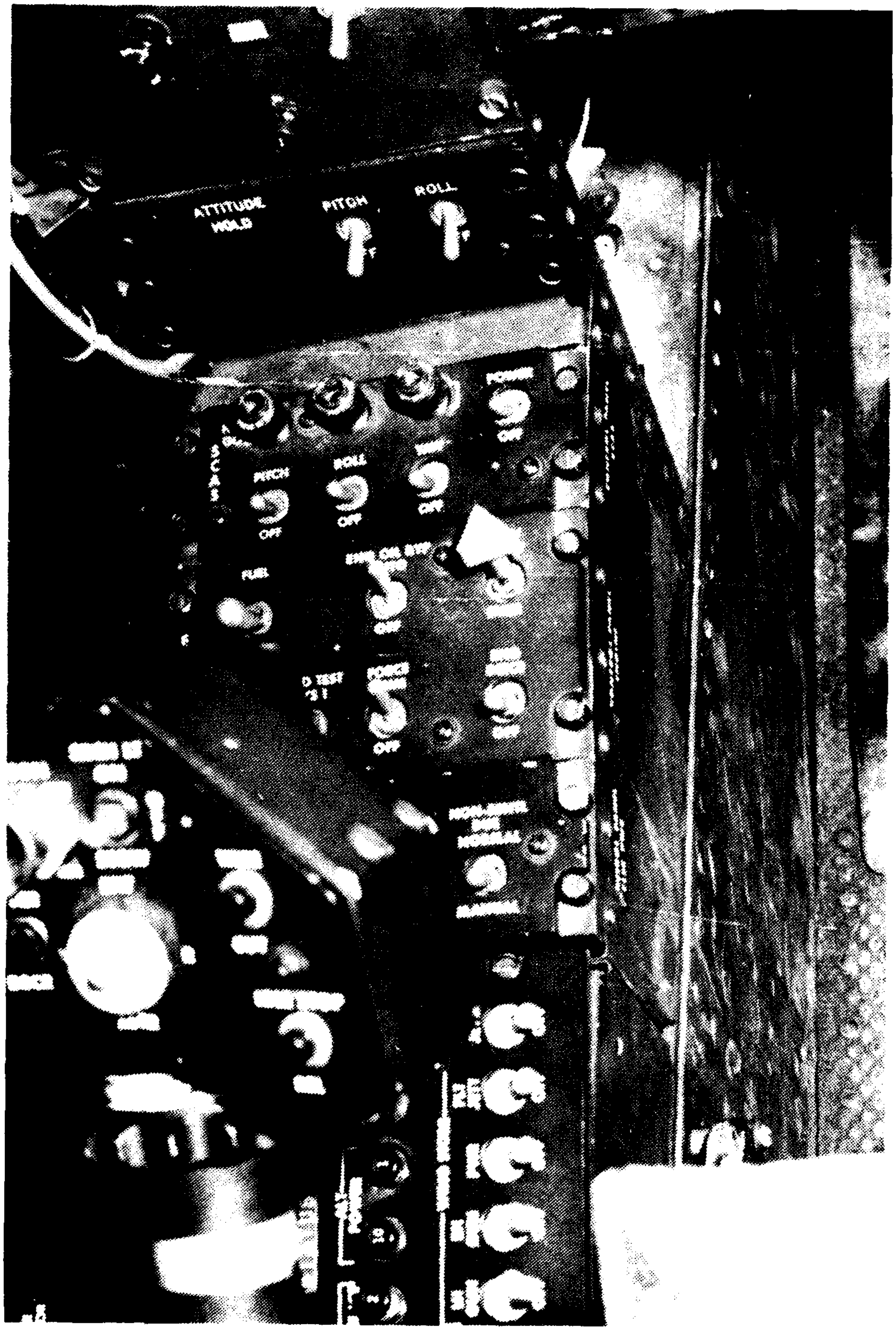


Figure B-15. Attitude Hold Control Panel

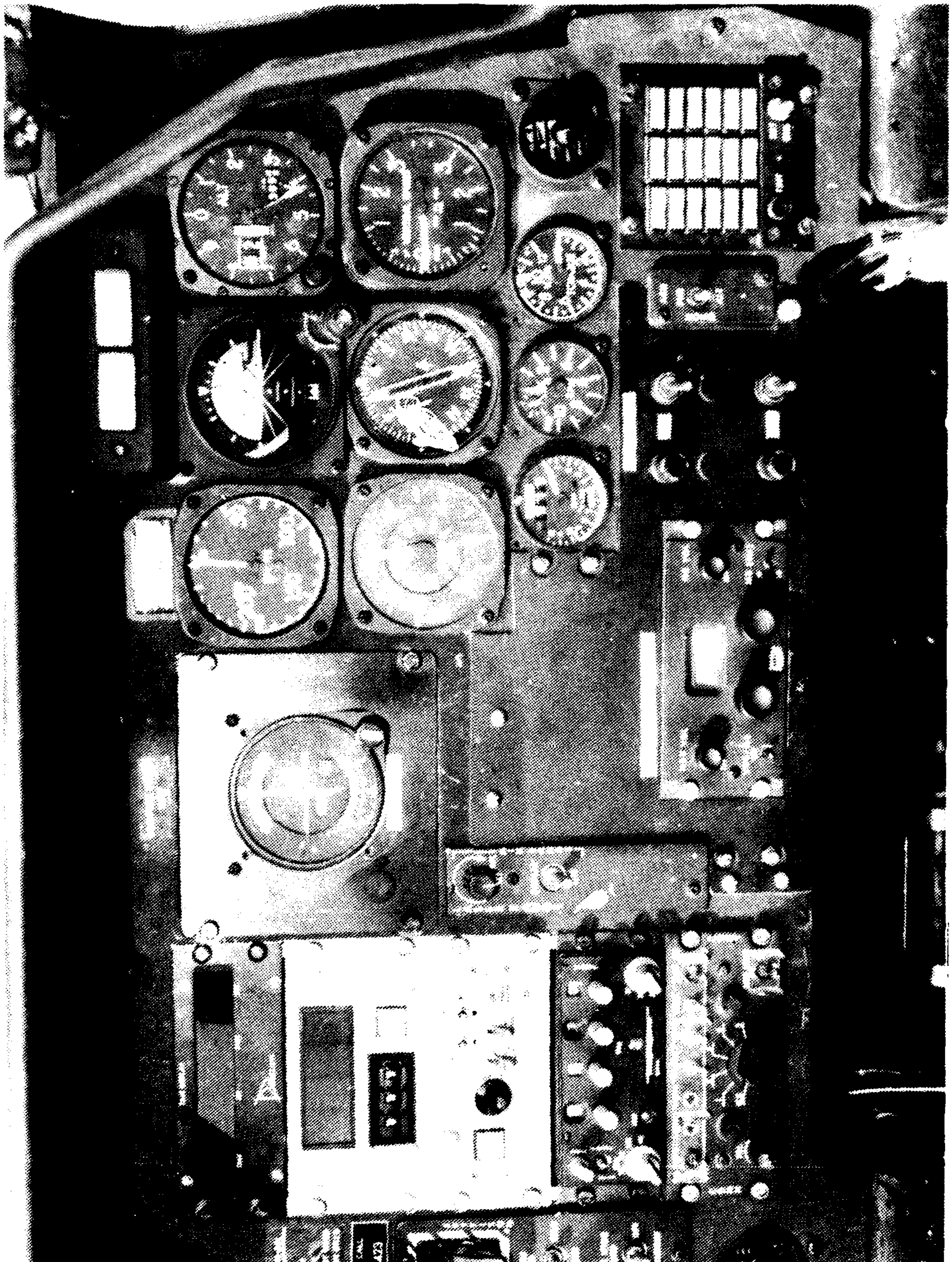


Figure B-16. Copilot/Gunner's Instrument Panel

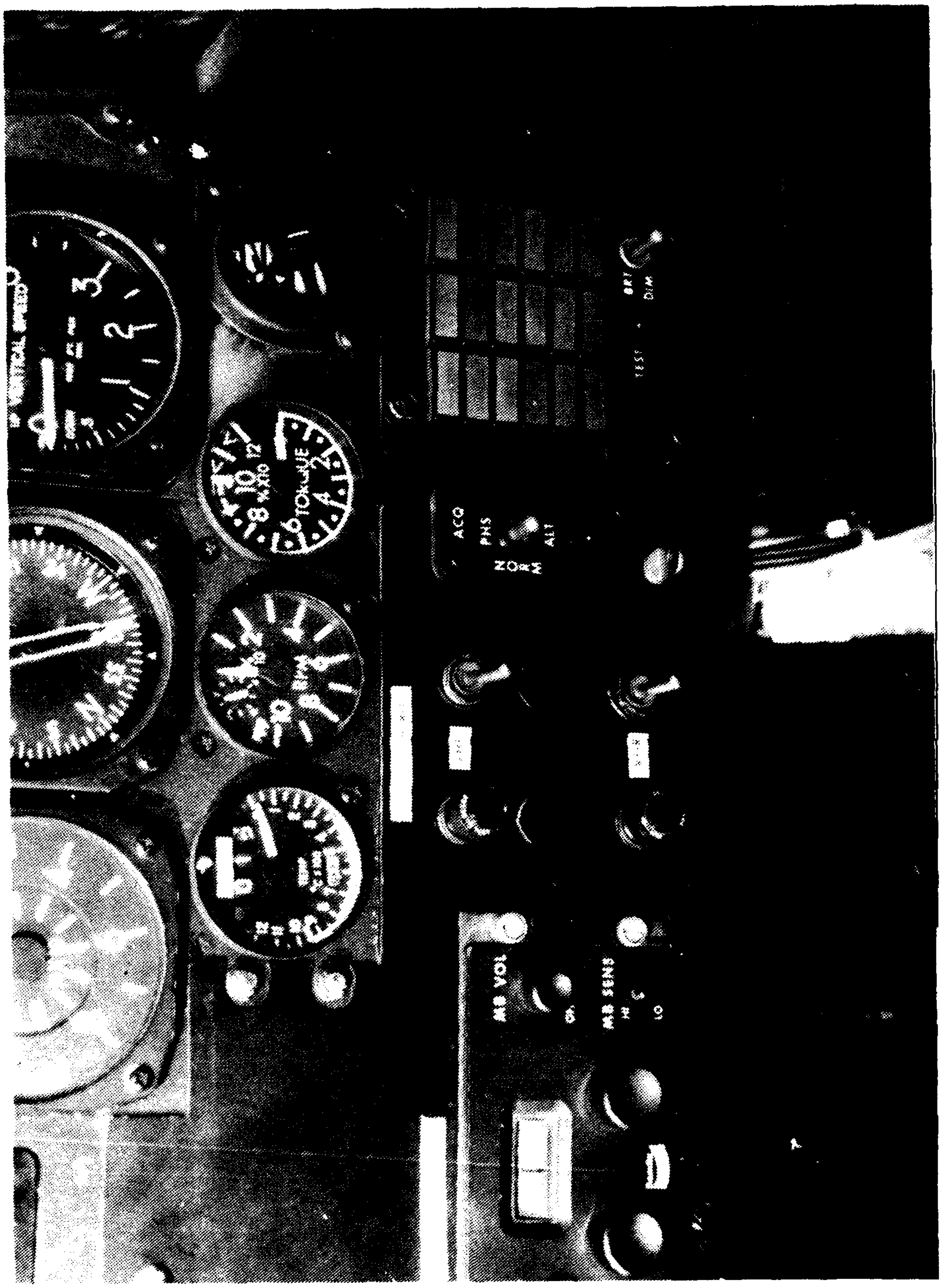


Figure B-17. VHF/VOR Take Control Panel

APPENDIX C. INSTRUMENTATION

1. The test instrumentation system was designed, calibrated, installed, and maintained by the U.S. Army Aviation Engineering Flight Activity (AEFA). An airborne data acquisition system utilizing pulse code modulation (PCM) encoding was employed during these tests. Data were obtained from calibrated instrumentation and were recorded on magnetic tape and/or displayed in the cockpit. The digital instrumentation system consisted of transducers, signal conditioning units, a ten-bit word pulse-coded modulation encoder, and an Ampex AR 700 tape recorder. The PCM data were telemetered to a ground station for in-flight monitoring. A boom extending 7 feet from the nose of the aircraft with the following sensors was mounted on the aircraft: swiveling pitot-static head, sideslip vane, angle-of-attack vane, and total-temperature probe. The boom airspeed system calibration is shown in figures C-1 and C-2.

2. The sensitive instrumentation and related special equipment installed includes the following:

Pilot Station and Instrument Panel

Angle of Sideslip
Airspeed (Boom)
Altitude (Boom)
Event Switch
Fuel Used (Totalizer)
Fuel Flow
Vertical Acceleration
Blade Flapping Margin

Copilot Station and Instrument Panel

Measured Gas Temperature (TGT)
Time Code
Event Switch
Instrumentation Controls and Displays

3. PCM parameters recorded on magnetic tape were as follows:

Airspeed (Boom)
Airspeed (Ship's System)
Altitude (Boom)
Altitude (Ship's System)
Angle of Attack
Rotor Speed
Engine Torque
Fuel Used
Fuel Flow
Gas Generator Speed (N1)
Power Turbine Speed (N2)
Measured Gas Temperature

FIGURE C-1

BOOM AIRSPEED CALIBRATION

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9610	198.5(AFT)	0.0	6210	15.5	321	LEVEL

NOTES: 1. TRAILING BOMB METHOD
2. BALL CENTERED FLIGHT

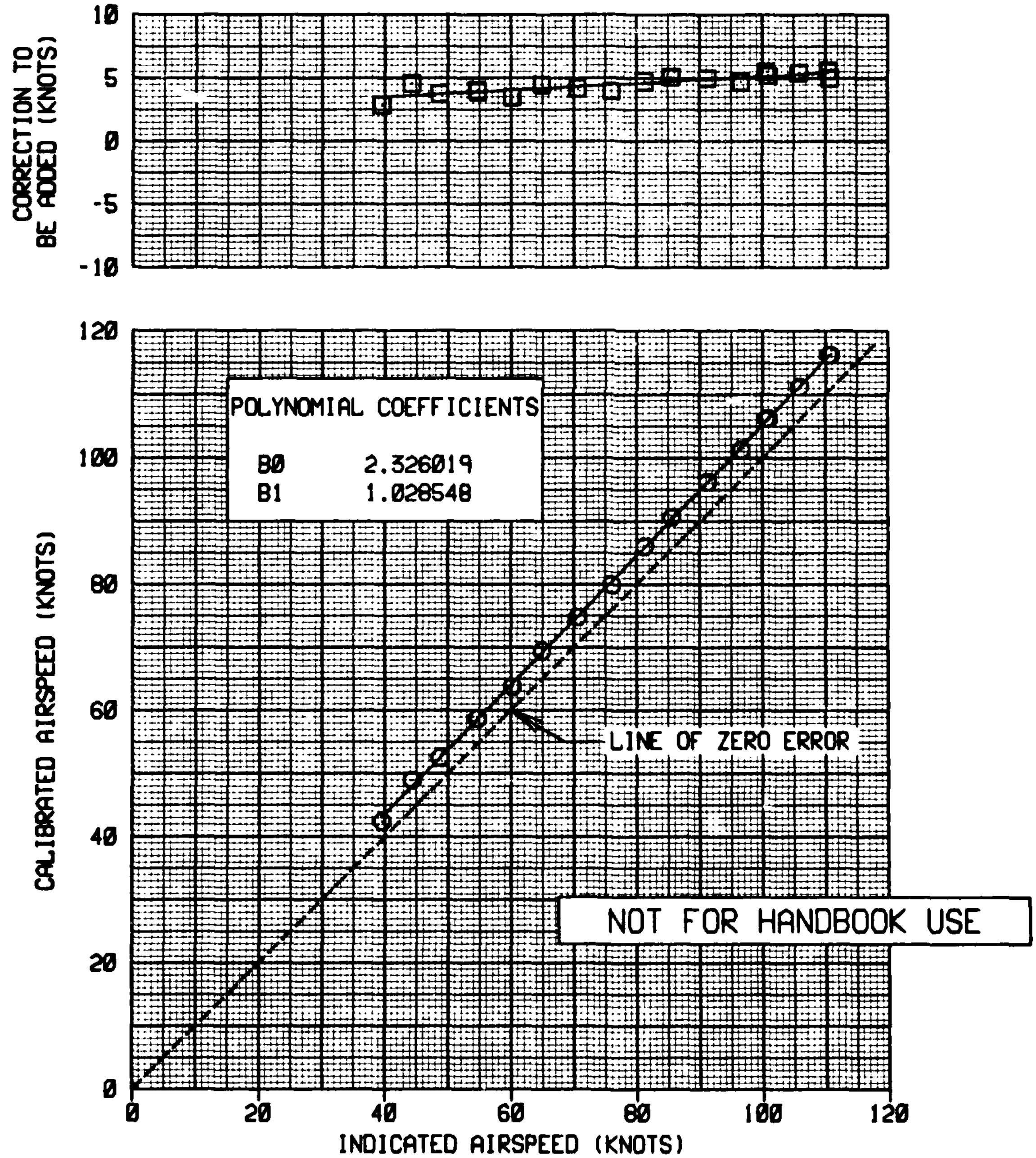


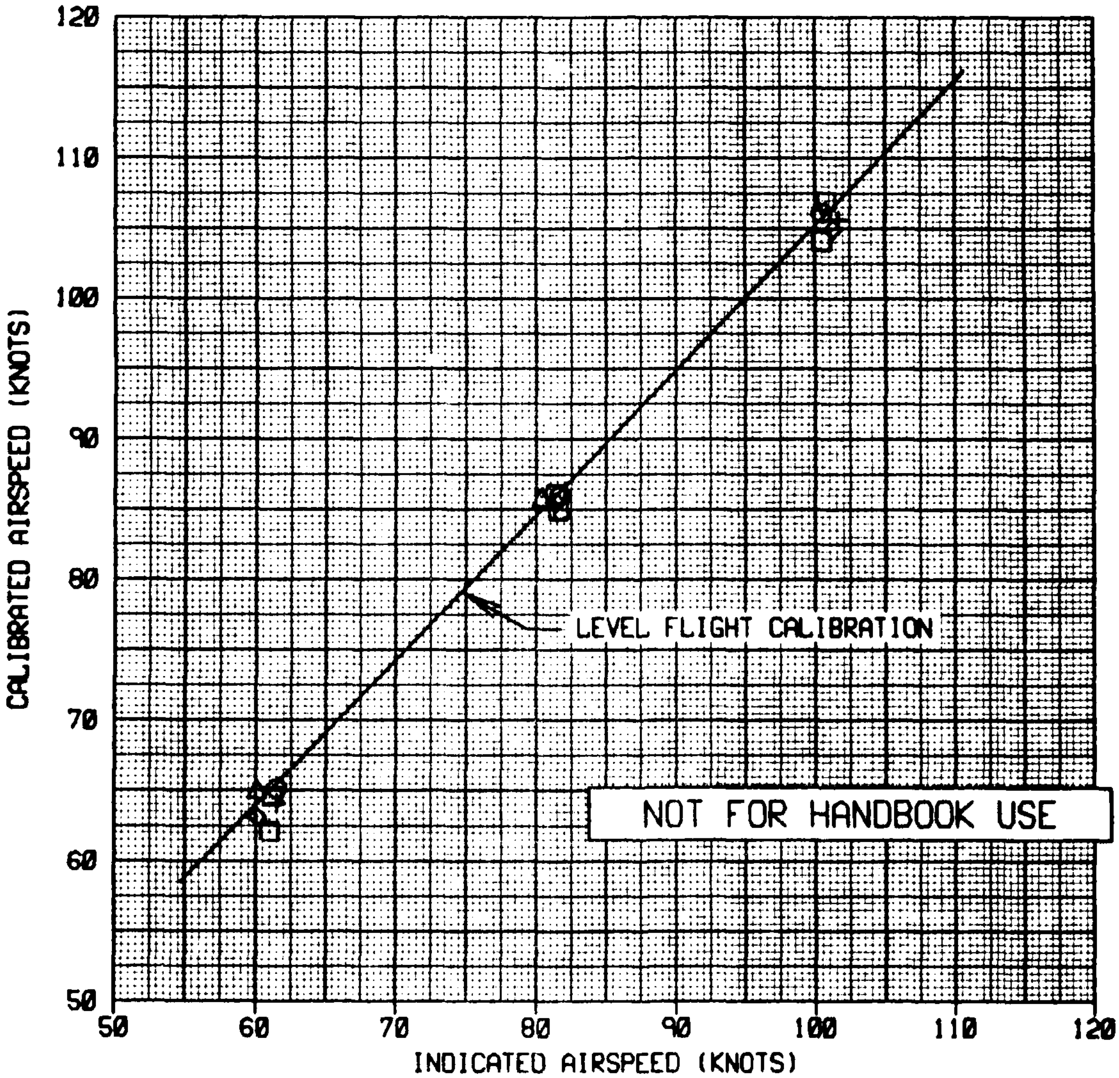
FIGURE C-2

BOOM AIRSPEED CALIBRATION

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9660	198.6(AFT)	0.0	5880	8.5	322

NOTES:
1. TRAILING BOMB METHOD
2. BALL CENTERED FLIGHT
3. □ - 500 FPM CLIMB
   ⊙ - 1000 FPM CLIMB
   △ - 1500 FPM CLIMB
   + - 500 FPM DESCENT
   ◇ - 1000 FPM DESCENT
   ⊡ - 1500 FPM DESCENT



Control Position
- Longitudinal
- Lateral
- Directional
- Collective

SCAS Actuator Positions
- Longitudinal
- Lateral
- Directional

Attitude
- Pitch
- Roll
- Yaw

Angular Rate
- Pitch
- Roll
- Yaw

Angle of Sideslip
Main Rotor Flapping Angle
Pilot/Engineer Event
Time Code
Record Number
Outside Air Temperature (Boom)
Center of Gravity Accelerations
- Longitudinal
- Lateral
- Vertical

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

PRETEST CHECKS AND CALIBRATIONS

1. The aircraft weight, longitudinal center of gravity (cg) location, and lateral cg location were determined prior to testing, and checked periodically throughout the tests. The weighing was accomplished with instrumentation installed. The aircraft was ballasted as necessary to achieve the desired takeoff gross weights and cg's.

2. A flight control system rigging check in accordance with reference 12, appendix A, was performed by the U.S. Army Aviation Engineering Flight Activity (AEFA) personnel to confirm proper rigging prior to testing. A calibration of the ship and boom pitot-static systems was conducted using the trailing bomb method. The presence of electronic interference between test instrumentation and aircraft flight control systems, avionics, instruments, and compass was determined and problems rectified prior to the instrument meteorological conditions (IMC) evaluation.

HANDLING QUALITIES

3. The mechanical characteristics of the cyclic control system were evaluated on the ground with the rotors and engine stopped and with external hydraulic and electrical power applied. Control forces were measured with a hand-held force gage applied at the center of the cyclic grip. Control positions were recorded on magnetic tape by aircraft test instrumentation and control forces were hand recorded. Control displacements from the neutral trim point were plotted as a function of control force.

4. Stability and control data were collected and evaluated using standard test methods described in reference 10, appendix A. The Handling Qualities Rating Scale presented in figure D-1 was used to augment pilot comments relative to handling qualities. Representative airspeeds and flight conditions were 80 knots indicated airspeed (KIAS) for climb, 100 KIAS for approach and holding, and 100 and 120 KIAS for cruise.

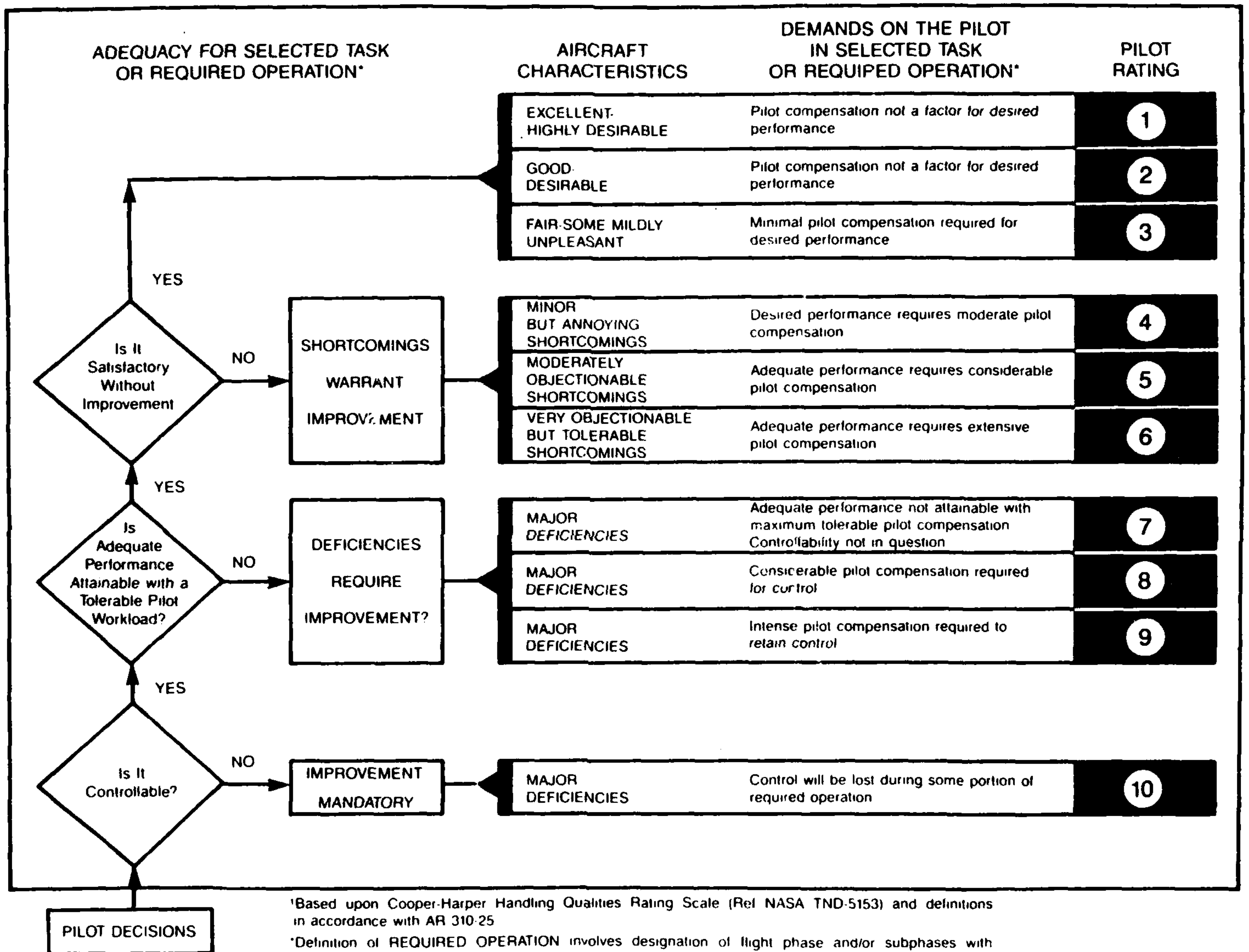
SIMULATED INSTRUMENT FLIGHT

5. Simulated instrument flight was conducted to qualitatively determine flight crew workloads in both smooth and turbulent atmospheric conditions. The pilot at the aft station and the copilot/gunner at the forward station functioned as an integrated crew. A description of the pilot IMC tasks, and the acceptable standards for those tasks, is provided in the aircrew training manual (ref 11, app A). All flights were made with either curtains installed in the aft cockpit or utilizing an instrument training hood. The ship's airspeed and altitude systems were used for all simulated instrument flight tasks. During typical IMC profile flights, all applicable regulations and flight procedures were followed.

DEFINITIONS

Deficiency

6. A defect or malfunction discovered during the life cycle of an item of equipment that constitutes a safety hazard to personnel; will result in serious damage to the equipment if



[1]Based upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) and definitions in accordance with AR 310-25

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions

Figure D-1. Handling Qualities Rating Scale

operation is continued; or indicates improper design or other cause of failure of an item or part, which seriously impairs the equipment's operational capability.

Shortcoming

7. An imperfection or malfunction occurring during the life cycle of equipment which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the materiel or end product.

APPENDIX E. TEST DATA

NOTE: (1) Refer to Table E-1.

Table E-1. Test Configurations

Symbol	Configuration[1]
BL	Standard AH-1F configuration (baseline); two TOW[2] missile launchers four dummy missiles on each outboard station, one 19-tube rocket launcher on each inboard station
ADS	Baseline, modified by additional pitot-static source provided through Air Data Subsystem
CYC	Baseline, modified by reduction of cyclic friction and/or cyclic centering spring preloads
FLAP	Baseline[3], modified by addition of a Gurney flap
FIN	Baseline[3] modified by removal of 90-degree gearbox fairings and addition of a ventral fin
GAIN	Baseline[3], modified by changes in pitch and roll SCAS[4] gains, and addition of attitude hold capability in pitch and roll channels
HOLD	Baseline[3,5], modified by addition of attitude hold capability in pitch and roll channels

NOTES:

[1]Various modifications of communication/navigation avionics cockpit arrangements were integrated with other configuration changes.
[2]TOW: Tube-launched, optically, tracked, wire command link.
[3]Reduced cyclic friction and reduced cyclic centering spring preloads.
[4]SCAS: Stability and Control Augmentation System.
[5]One flight conducted in clean (no wing stores) external configuration.

FIGURE E-1

LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
PILOT STATION

AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LATERAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 2.0 LB AFT
   1.8 LB FORWARD
7. CENTERING SPRING PRELOAD 6.0 LB
8. AVERAGE FORCE GRADIENT 1.9 LB/IN

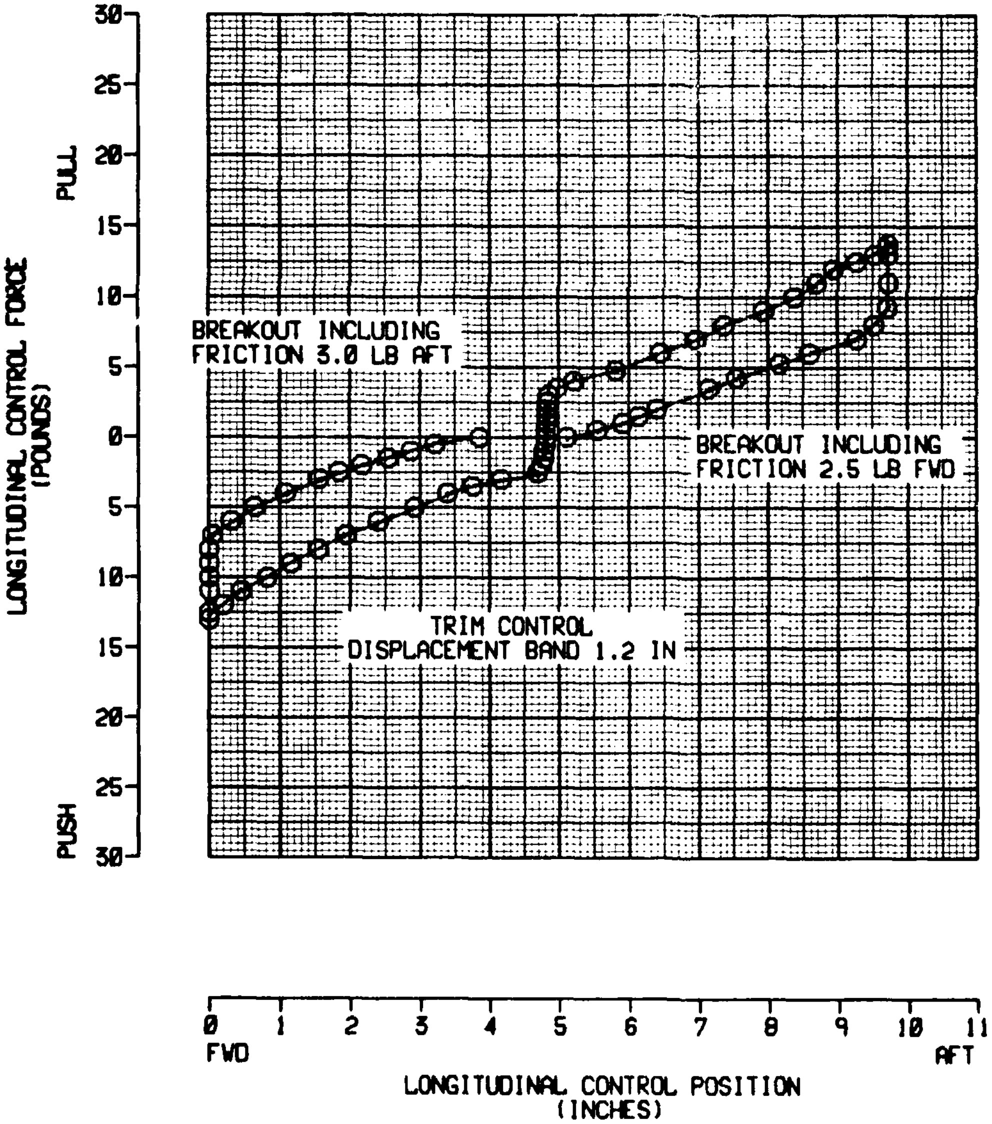


FIGURE E-2
LATERAL CONTROL SYSTEM CHARACTERISTICS
PILOT STATION
AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LONGITUDINAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.8 LB LEFT
   1.9 LB RIGHT
7. CENTERING SPRING PRELOAD 6.0 LB
8. AVERAGE FORCE GRADIENT 1.5 LB/IN

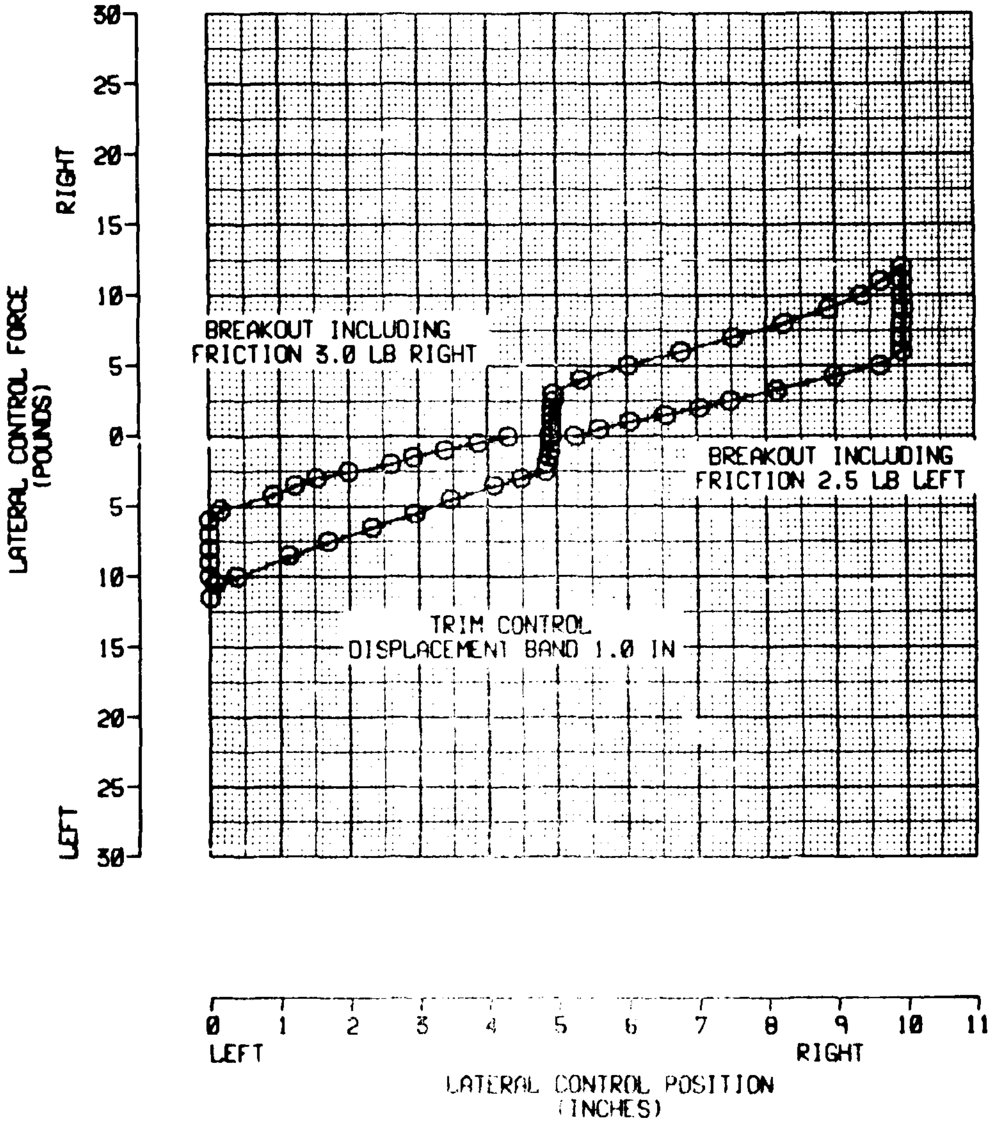


FIGURE E-3

LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
COPILOT/GUNNER STATION
AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LATERAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 2.0 LB AFT
   1.8 LB FORWARD
7. CENTERING SPRING PRELOAD 6.0 LB
8. AVERAGE FORCE GRADIENT 4.7 LB/IN

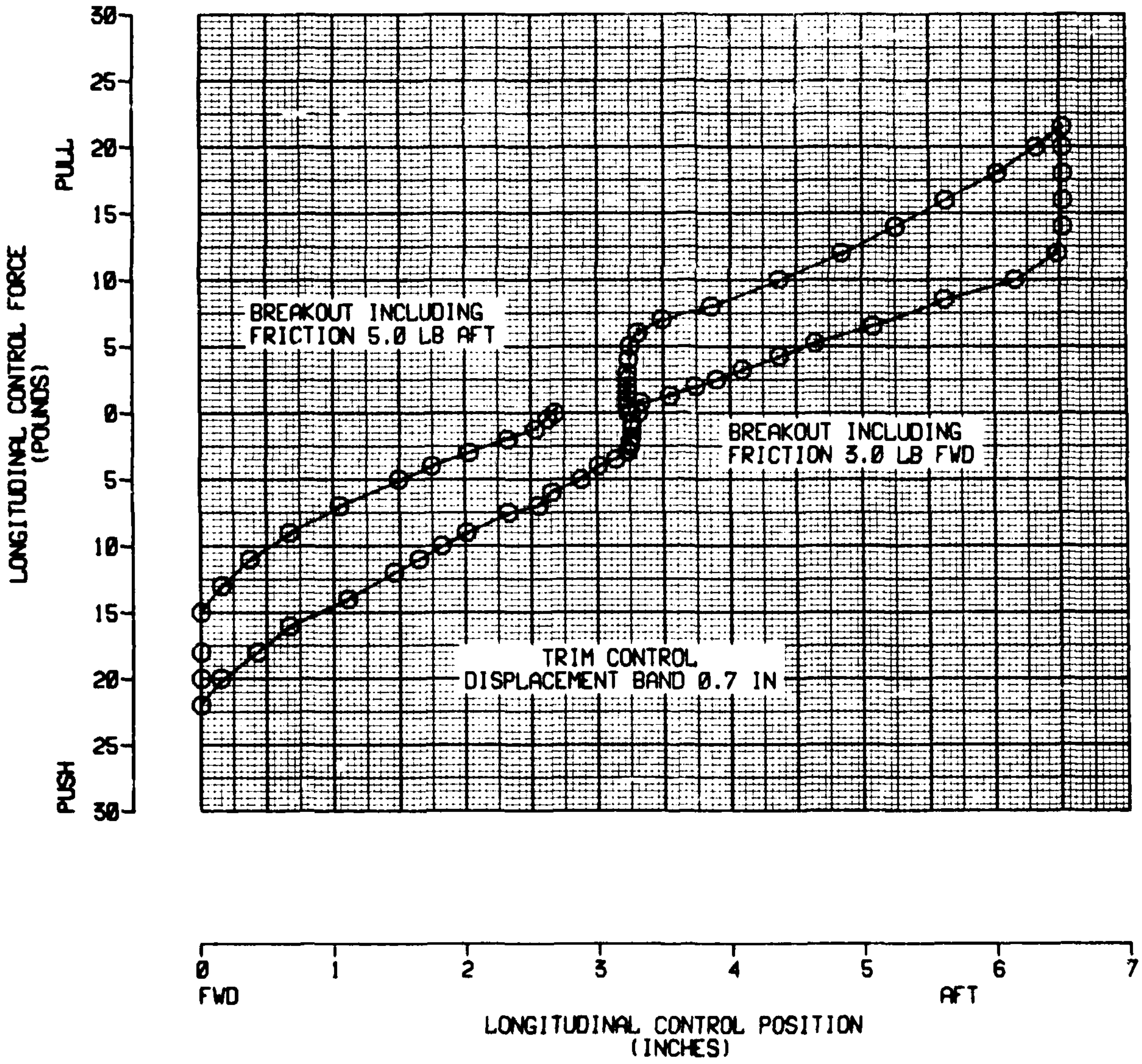


FIGURE E-4

LATERAL CONTROL SYSTEM CHARACTERISTICS
COPILOT/GUNNER STATION

AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LONGITUDINAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.8 LB LEFT
   1.9 LB RIGHT
7. CENTERING SPRING PRELOAD 6.0 LB
8. AVERAGE FORCE GRADIENT 4.5 LB/IN

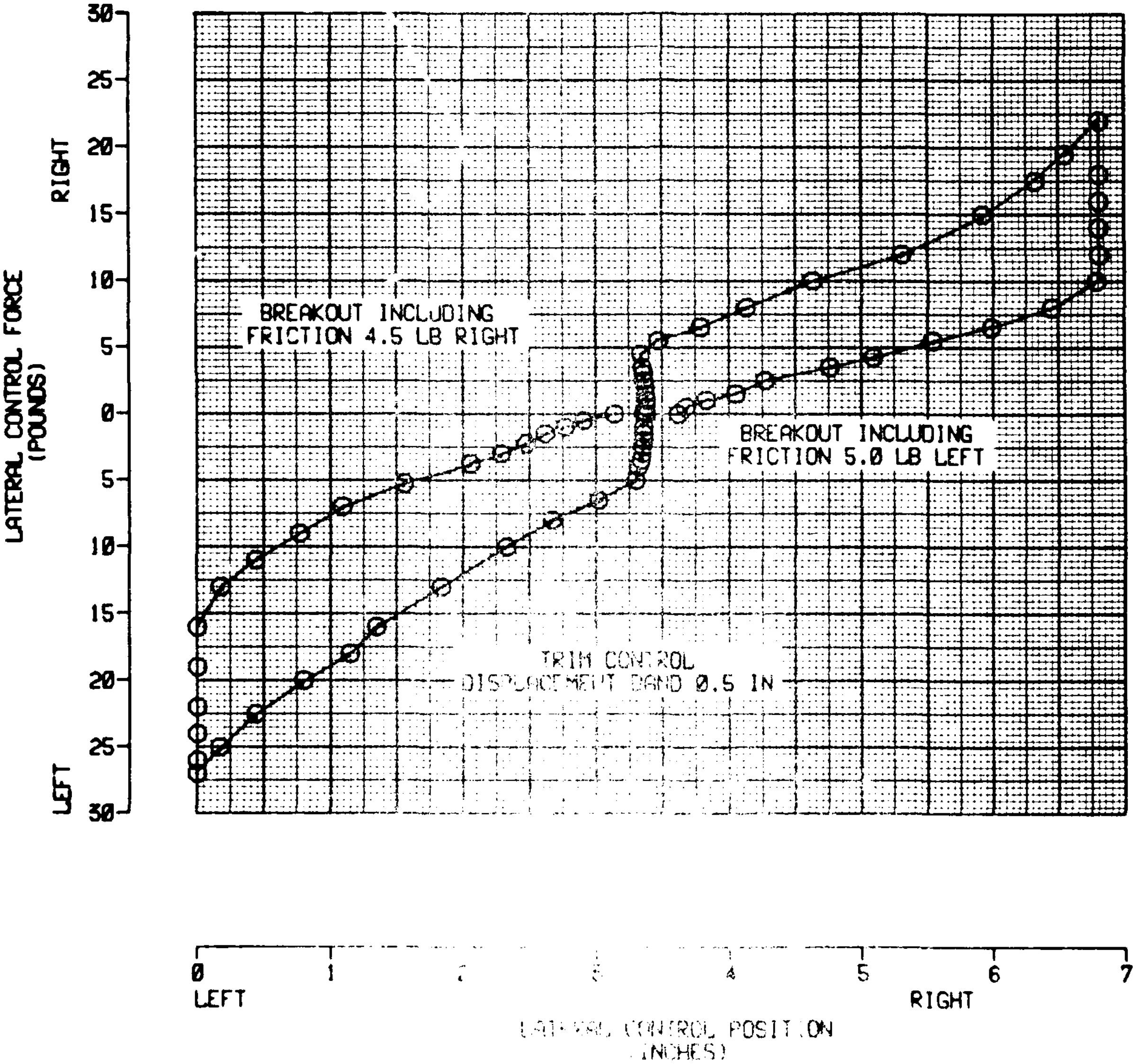


FIGURE E-5

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9590	198.6(AFT)	0.0	6220	15.5	321	□ -LEVEL ○ -1000 FPM CLIMB △ -1000 FPM DESC. + -1500 FPM CLIMB ◇ -1500 FPM DESC.

NOTES: 1. BALL CENTERED FLIGHT
2. SCAS ON

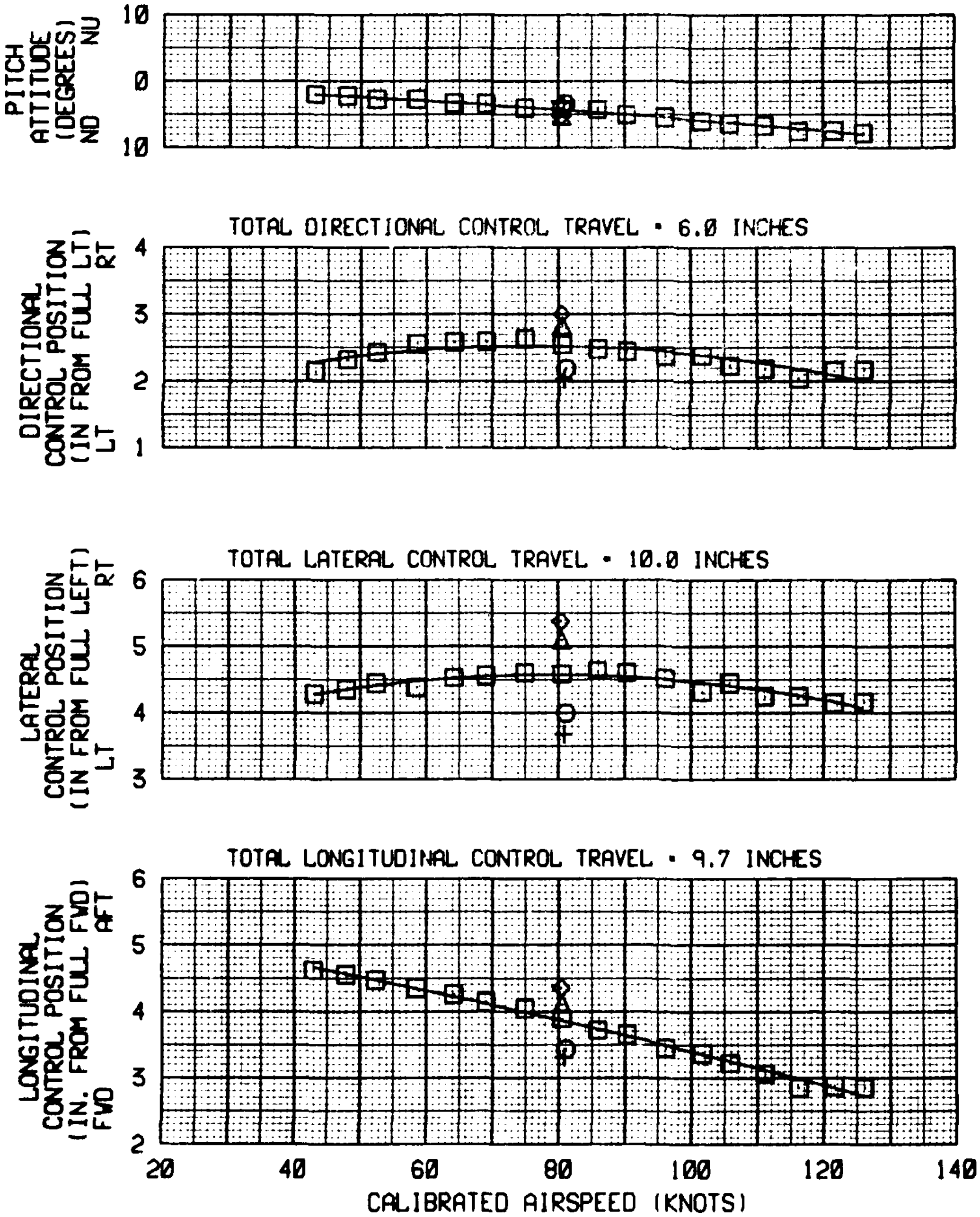


FIGURE E-6

STATIC LONGITUDINAL STABILITY

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9660	198.6(AFT)	0.0	5000	1.0	325	LEVEL

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. SCAS ON

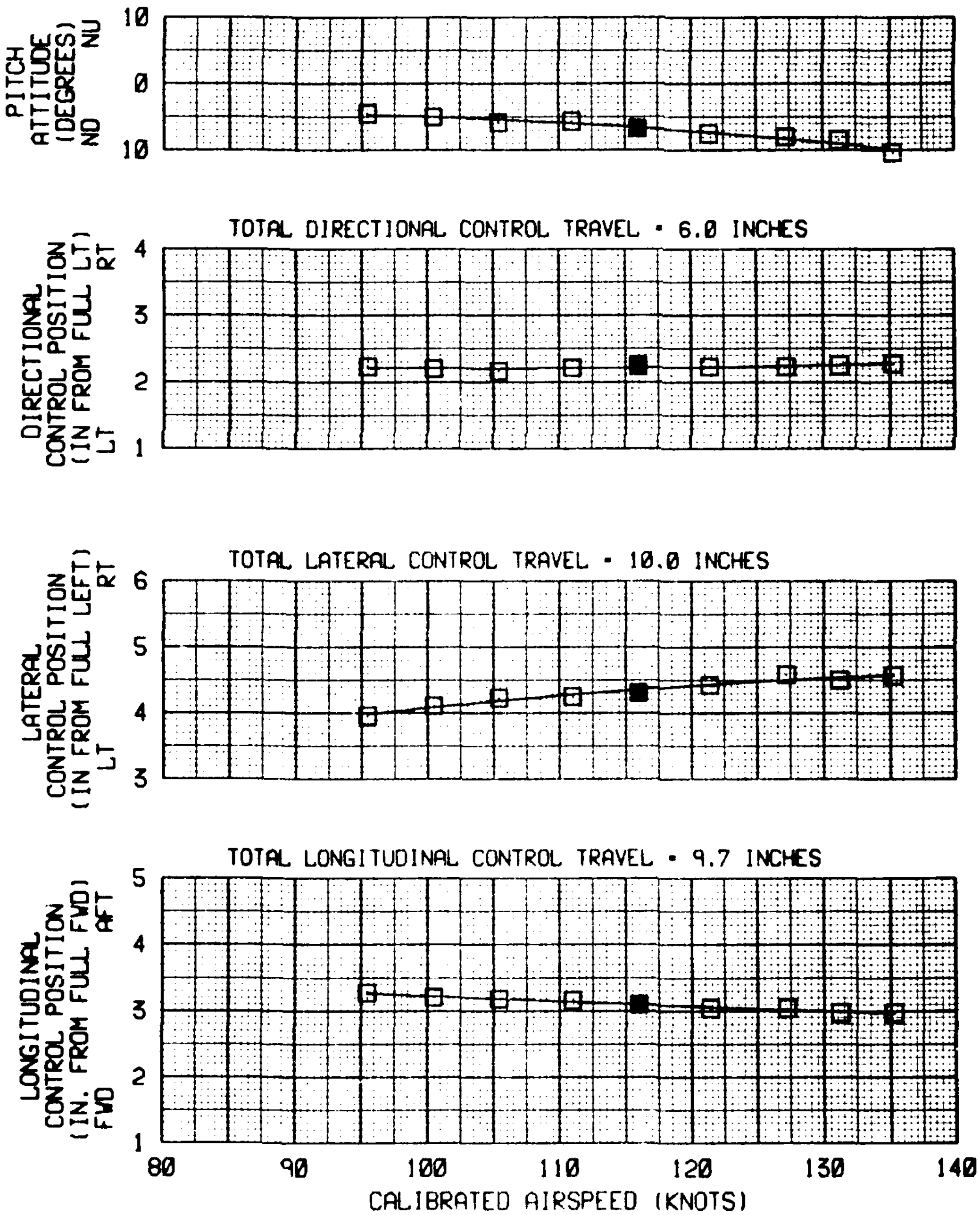


FIGURE E-7

STATIC LATERAL-DIRECTIONAL STABILITY

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
9340	199.4(AFT)	0.0	5840	21.0	324	116

NOTES: 1. SHADED POINT DENOTES BALL CENTERED FLIGHT
2. SCAS ON

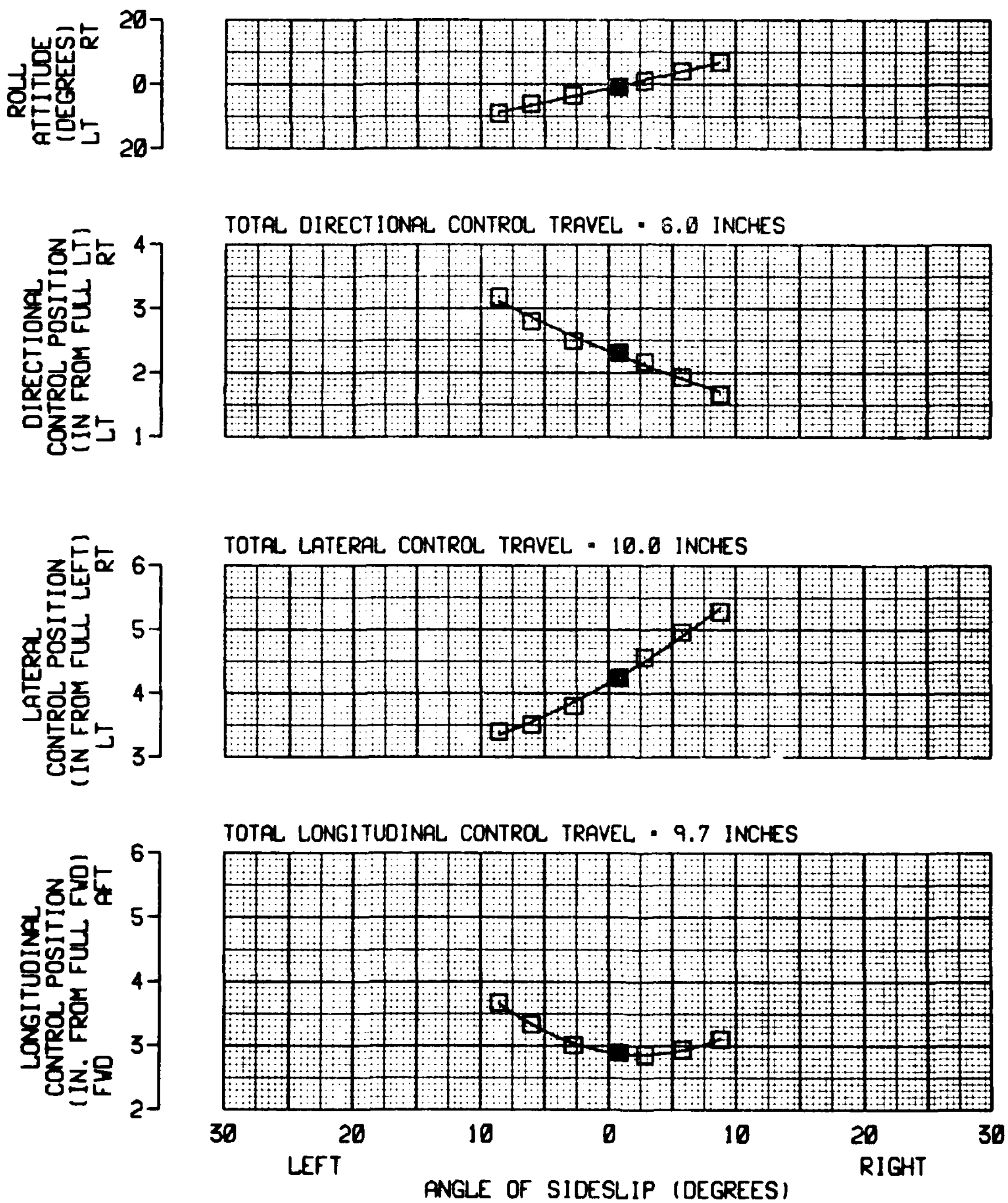


FIGURE E-8

LONG TERM RESPONSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9410	[illegible] (AFT)	0.2	5470	2.0	323	104	DESCENT

NOTE: SCAS ON

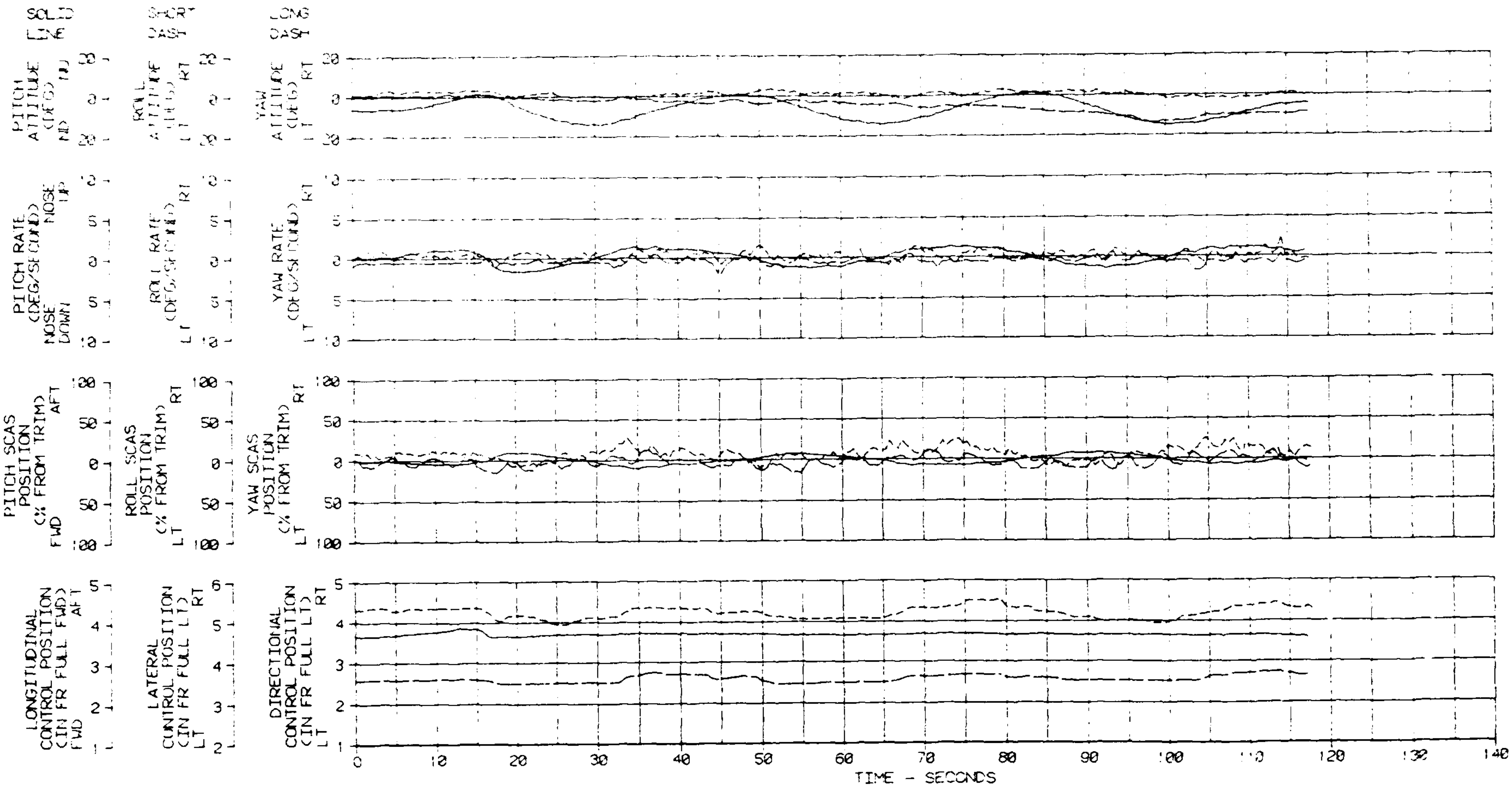


FIGURE E-9

AFT LONGITUDINAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9800	198 7(AFT)	0 0	6280	4 5	321	116	LEVEL

NOTE SCAS ON

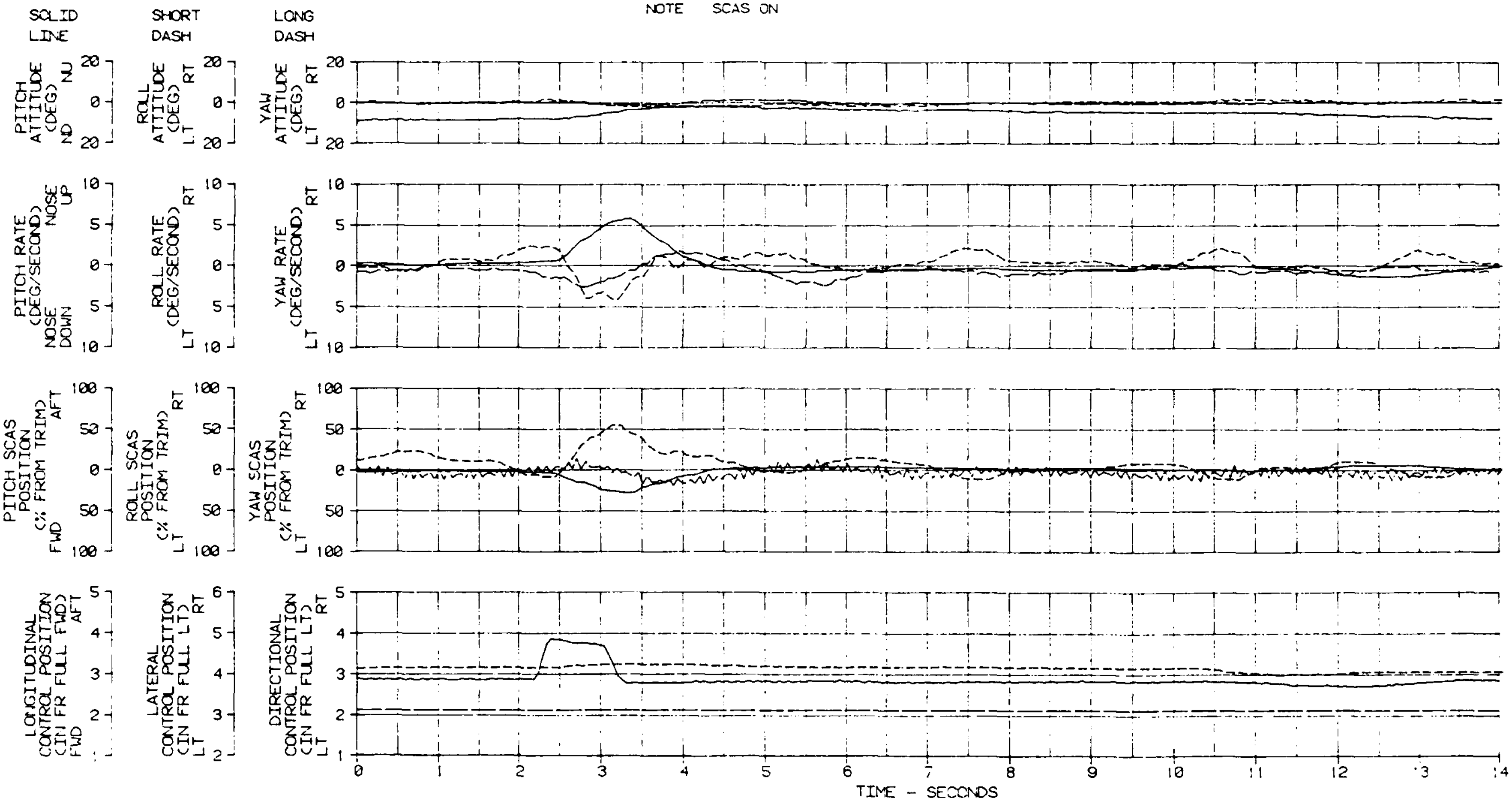


FIGURE E-10

LEFT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9650	198.9(AFT)	0.0	6270	4.5	321	115	LEVEL

NOTE: SCAS ON

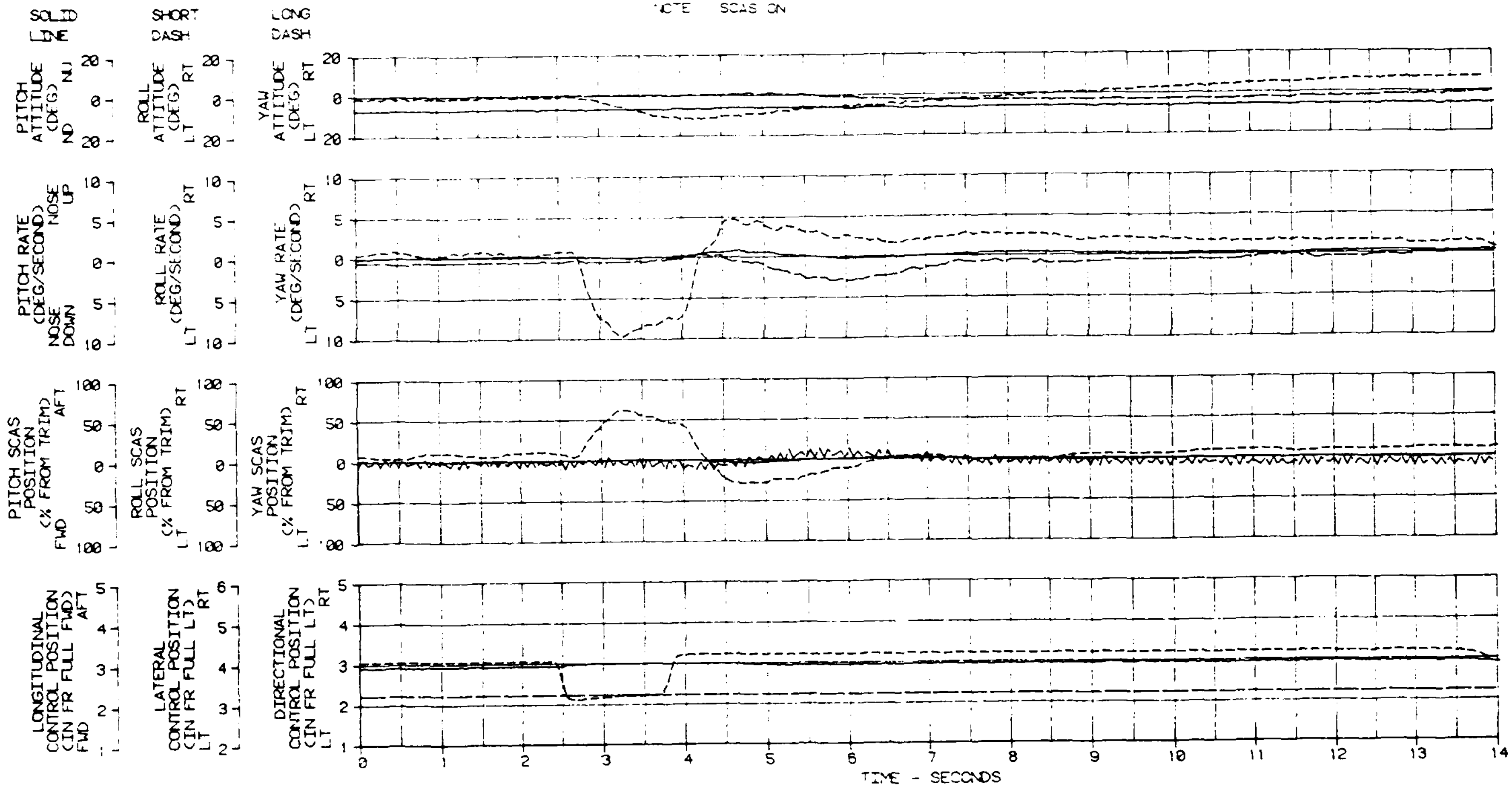


FIGURE E-11

RIGHT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9590	198.8(AFT)	0.0	6460	3.5	321	116	LEVEL

NOTE: SCAS ON

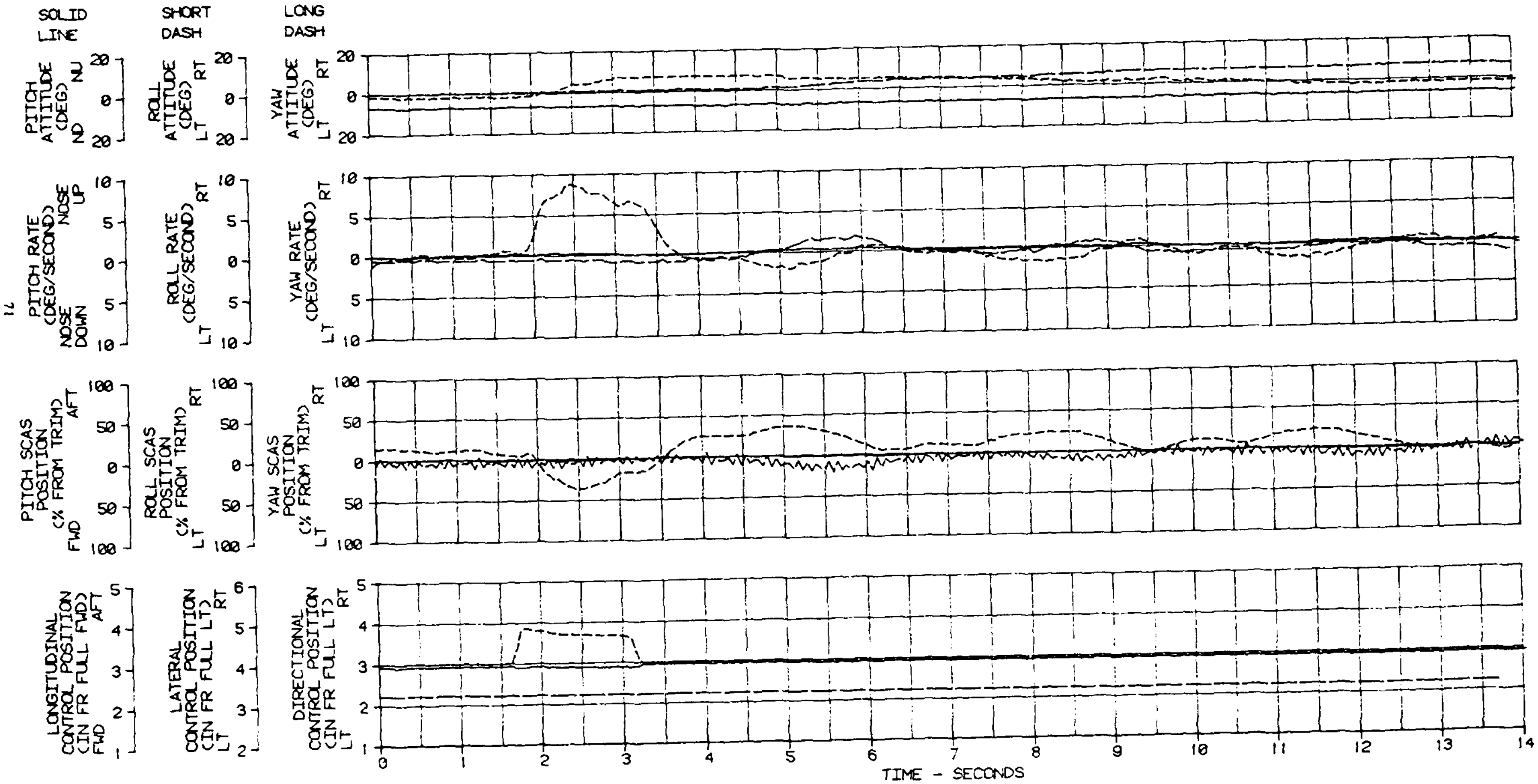


FIGURE E-12

RIGHT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9140	198 6(AFT)	0 0	5550	4.5	321	72	CLIMB

NOTE SCAS ON

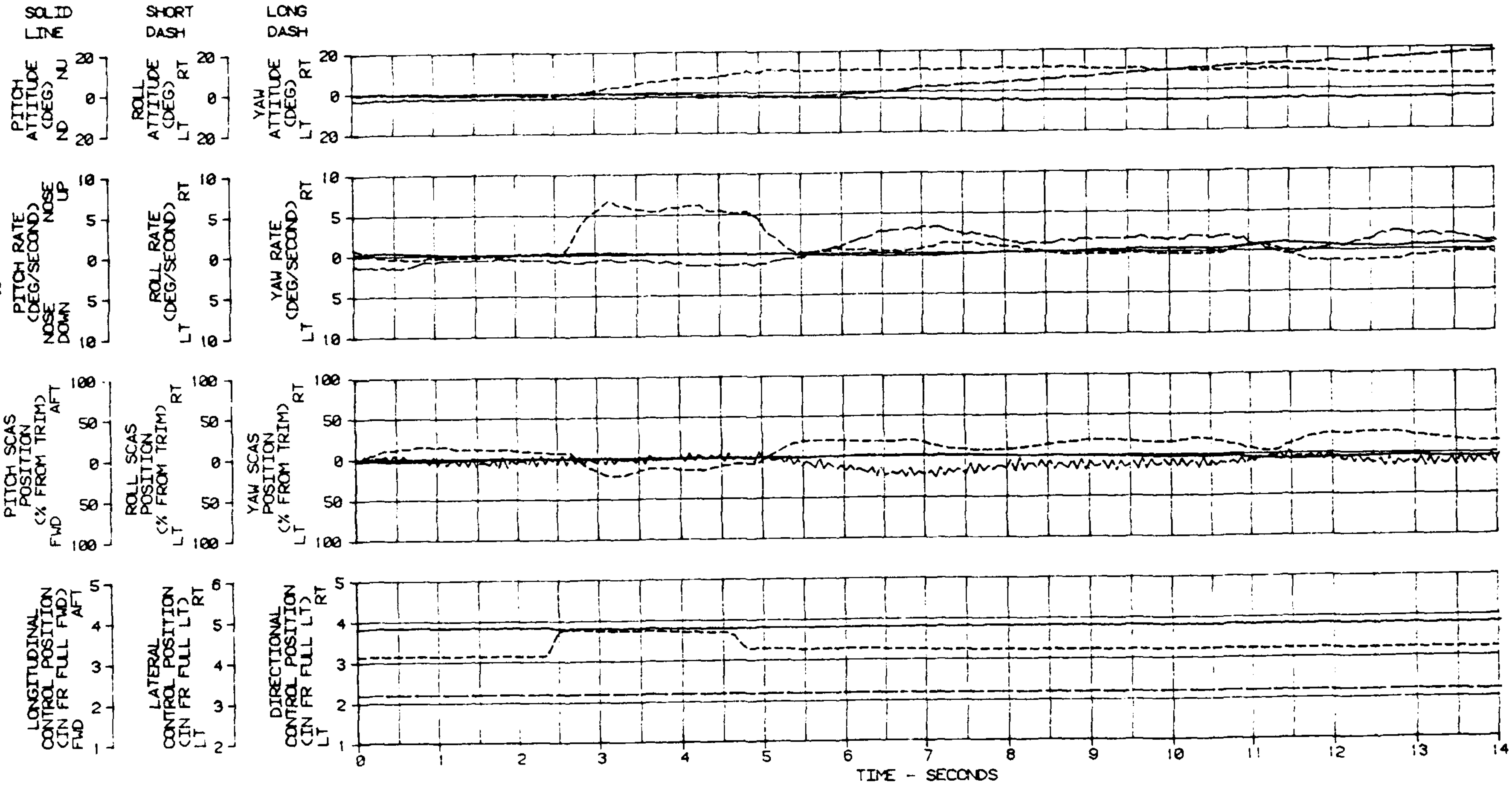


FIGURE E-13

RIGHT PEDAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9820	198.5(AFT)	0.0	5880	8.5	323	117	LEVEL

NOTE: SCAS ON

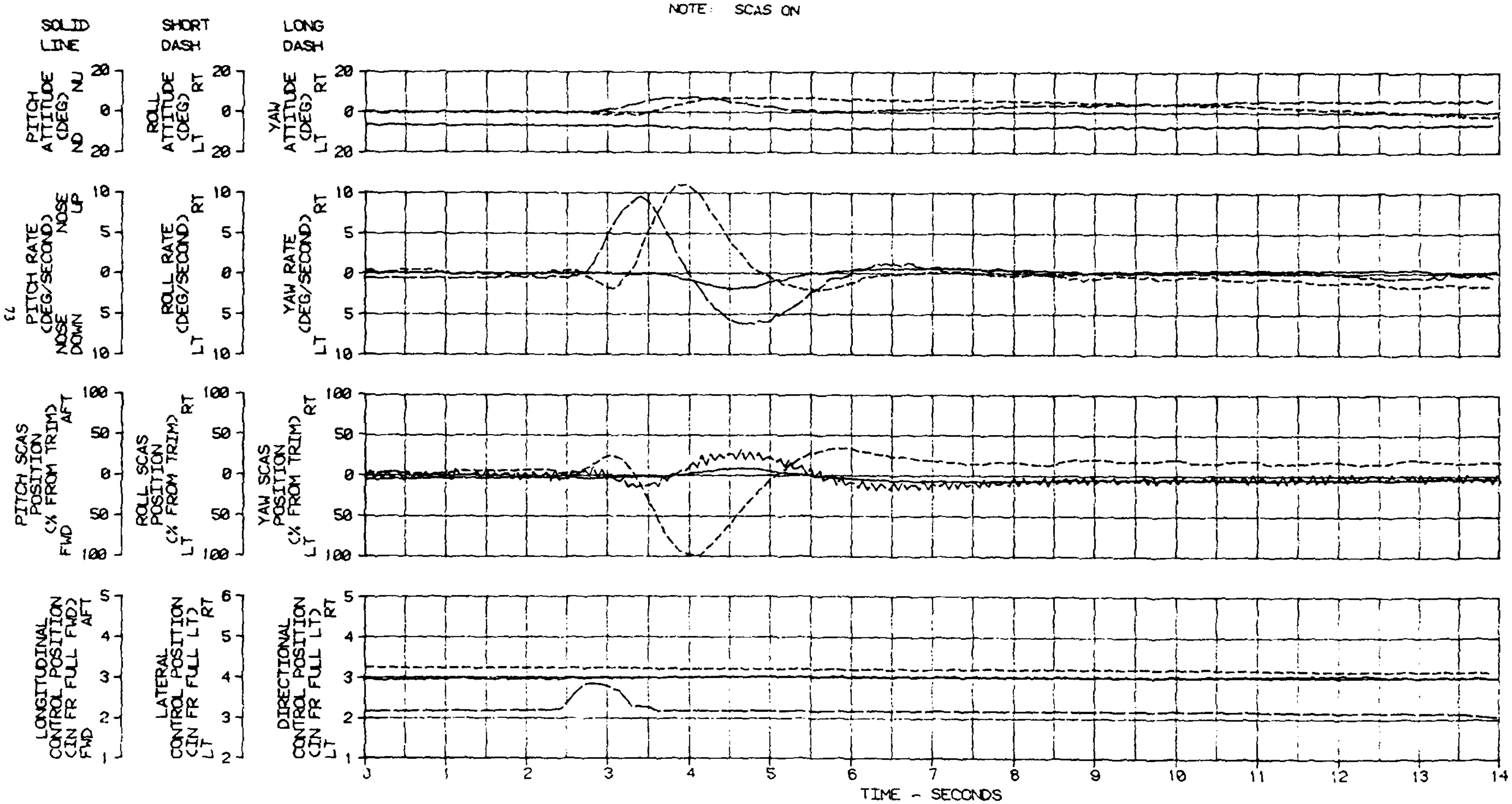


FIGURE E-14

RELEASE FROM SIDESLIP
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9580	198.6(AFT)	0.0	5590	9.0	322	117	LEVEL

NOTE: SCAS ON

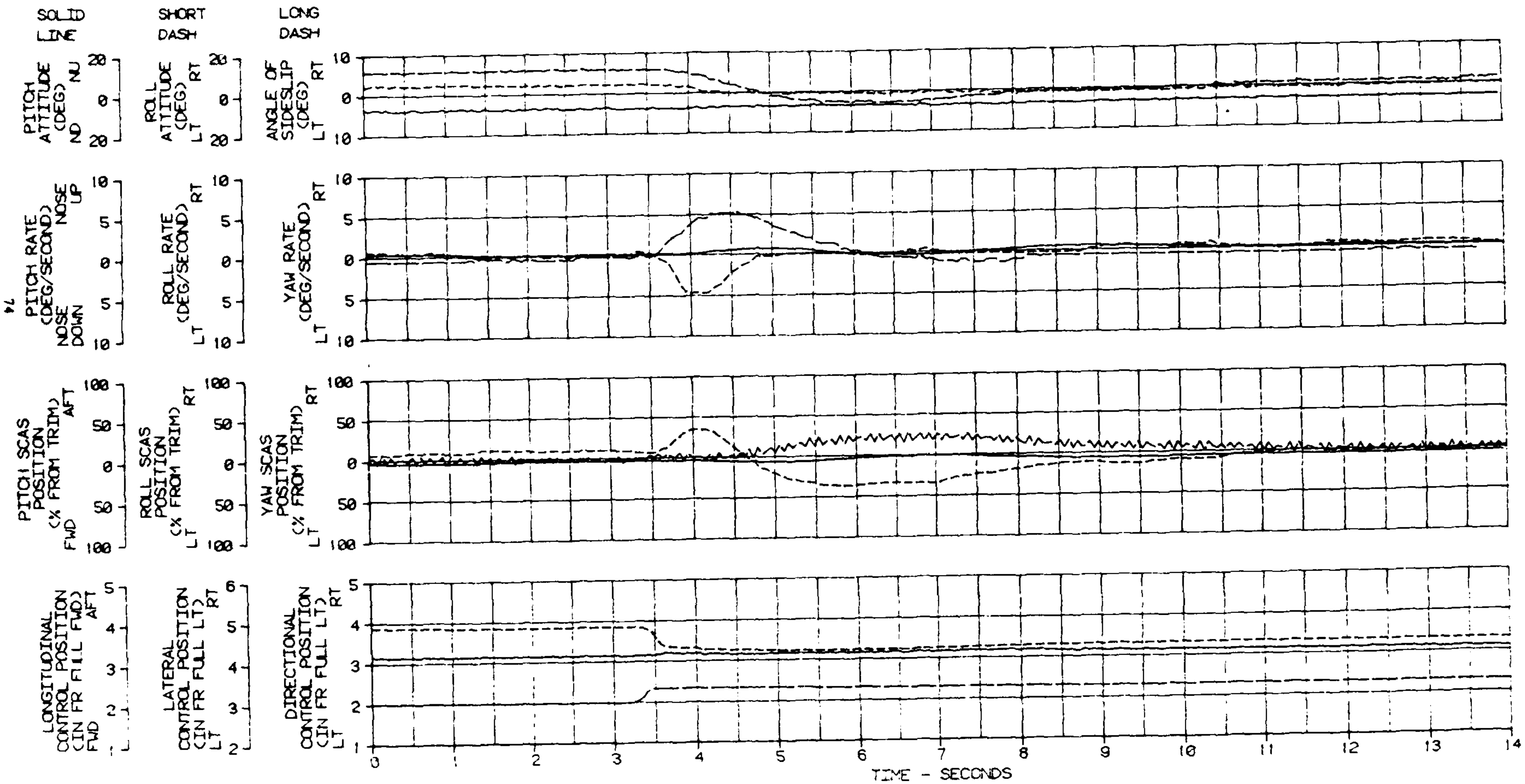


FIGURE E-15

ADVERSE/PROVERSE YAW CHARACTERISTICS
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9560	198.5(AFT)	0.0	5600	8.5	322	113	LEFT TURN

NOTES: 1. SCAS ON
2. PEDALS FIXED

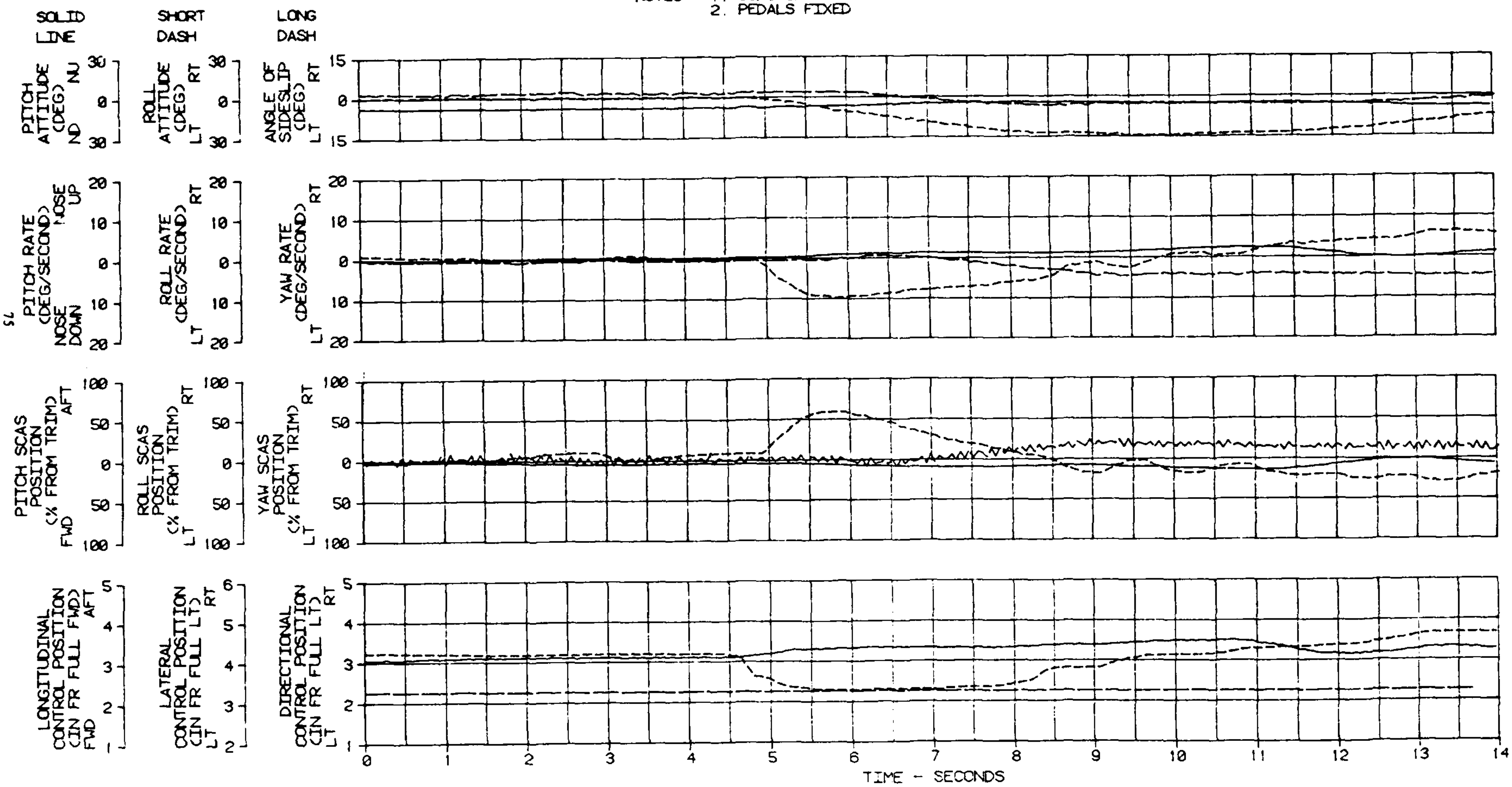


FIGURE E-16

SPIRAL STABILITY
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9180	198.3(AFT)	0.0	6080	0.5	321	114	LEVEL

NOTE: SCAS ON

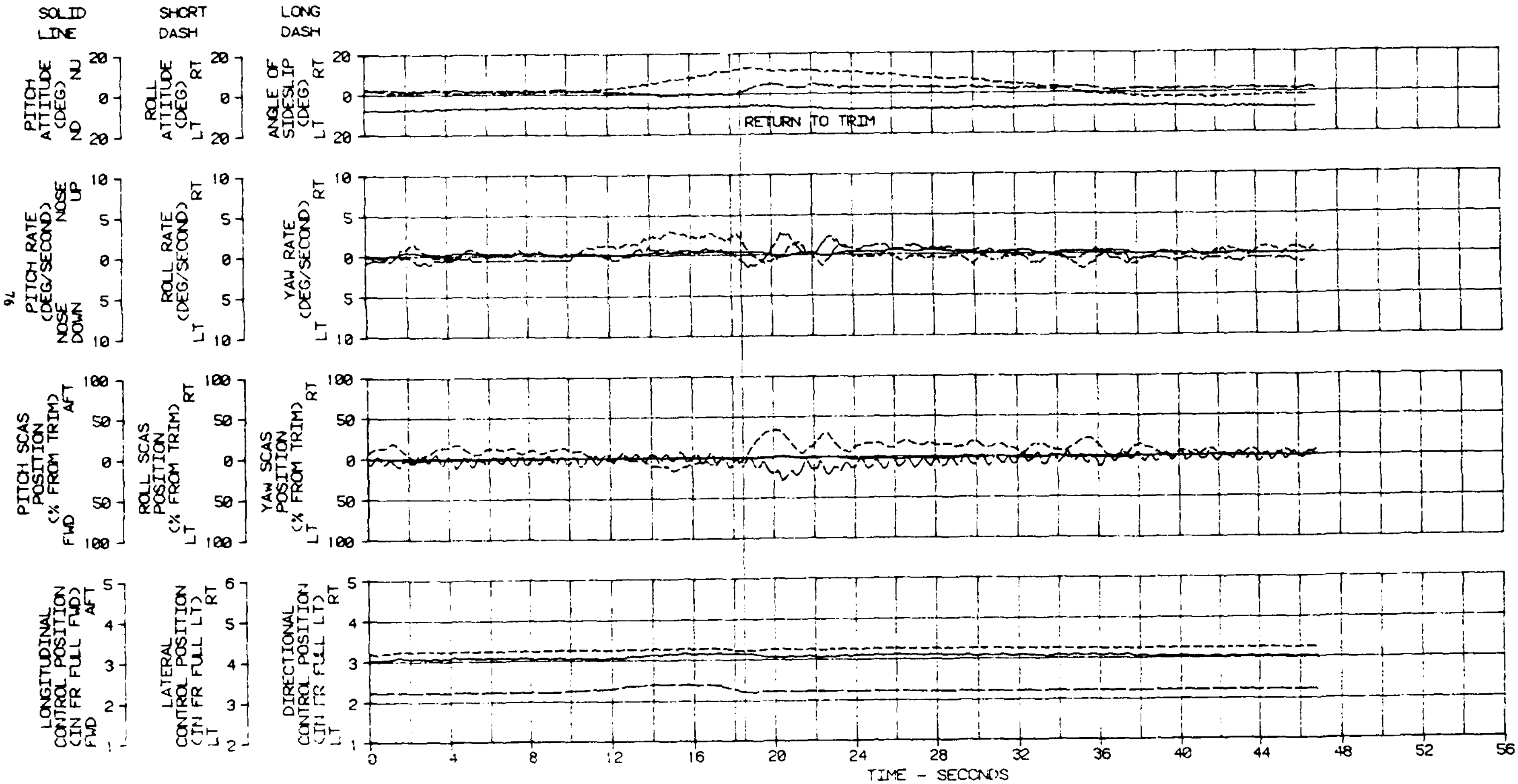


FIGURE E-17

SIMULATED ENGINE FAILURE

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)	FLIGHT CONDITION
9780	198.5(AFT)	0.0	7070	6.5	322	96	64	LEVEL

NOTES: 1. ENTRY FROM BALL CENTERED FLIGHT
2. SCAS ON

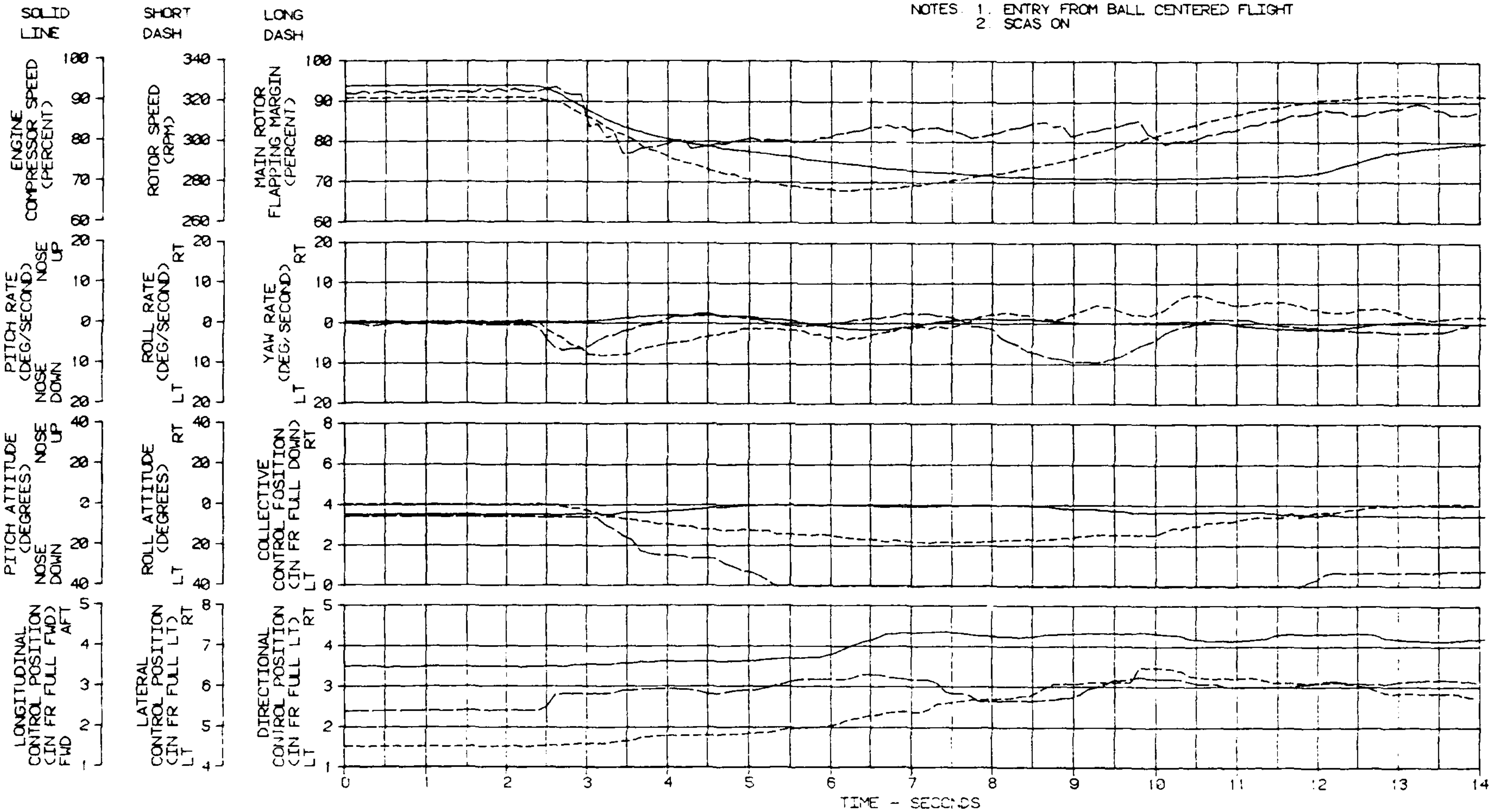


FIGURE E-18

SCAS DISENGAGEMENT
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9370	198 4(AFT)	0 0	5600	8 5	322	115	LEVEL

NOTE ENTRY FROM BALL CENTERED FLIGHT

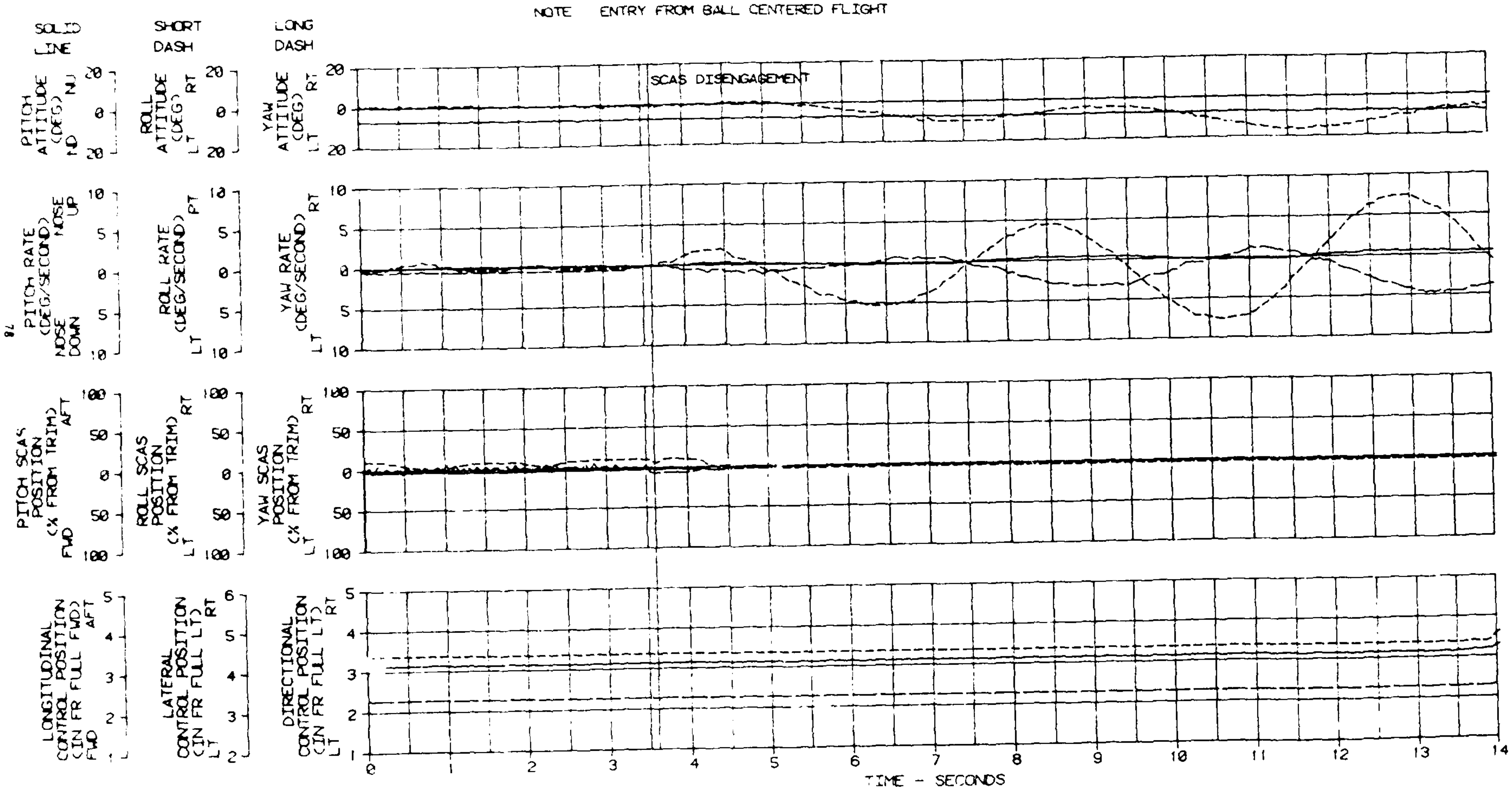


FIGURE E-19

ENGINE TORQUE OSCILLATIONS
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9680	198.5(AFT)	0.0	6670	17.0	320	111	LEVEL

NOTE: SCAS ON

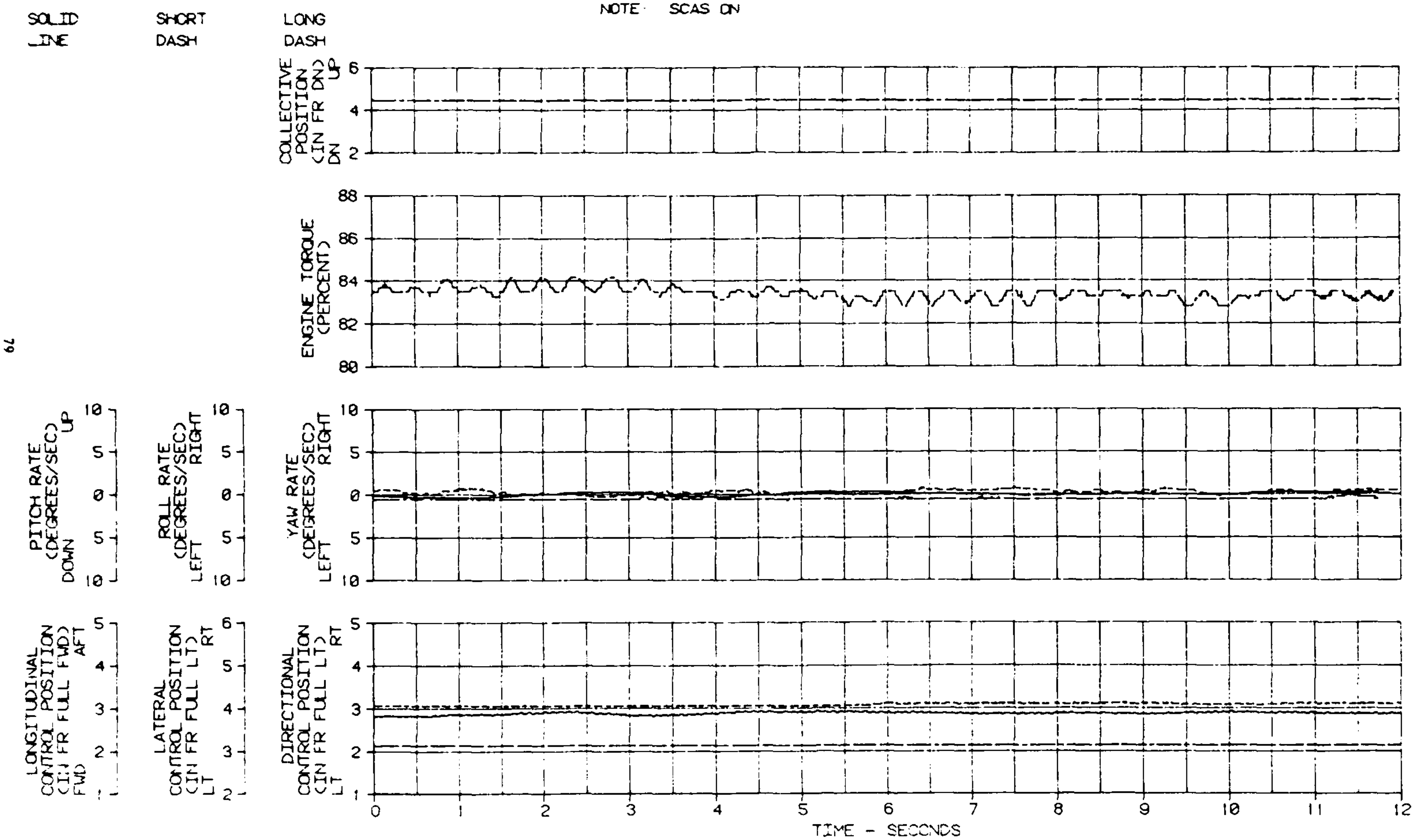


FIGURE E-20

SHIP AIRSPEED CALIBRATION

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9604	198.5(AFT)	0.0	6210	15.5	321	LEVEL

NOTES: 1. TRAILING BOMB METHOD
2. BALL CENTERED FLIGHT

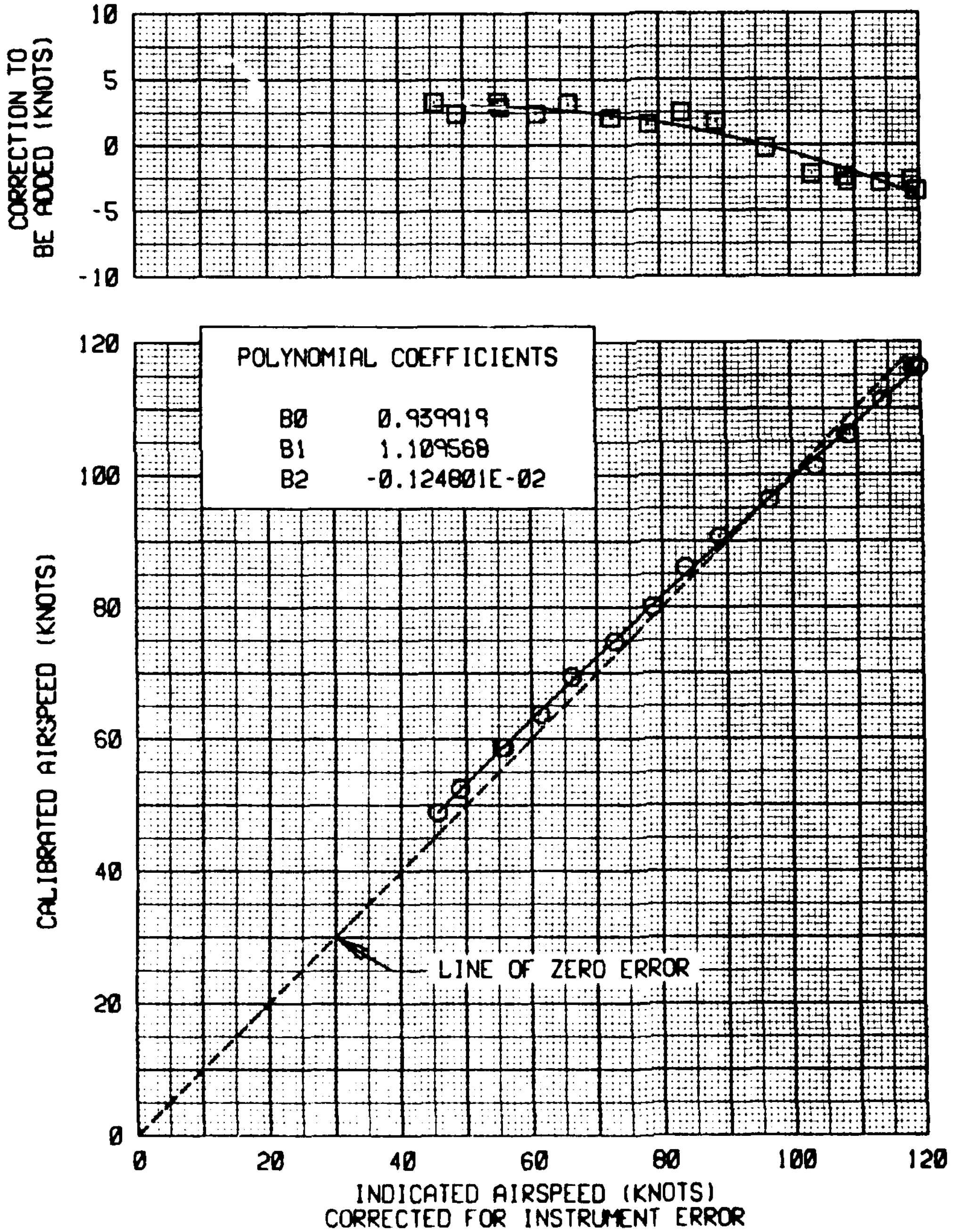


FIGURE E-21

SHIP AIRSPEED CALIBRATION

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9660	198.6(AFT)	0.0	5880	8.5	322

NOTES: 1. TRAILING BOMB METHOD
2. BALL CENTERED FLIGHT
3. ⊡ - 500 FPM CLIMB
⊙ - 1000 FPM CLIMB
△ - 1500 FPM CLIMB
+ - 500 FPM DESCENT
◇ - 1000 FPM DESCENT
⊡ - 1500 FPM DESCENT

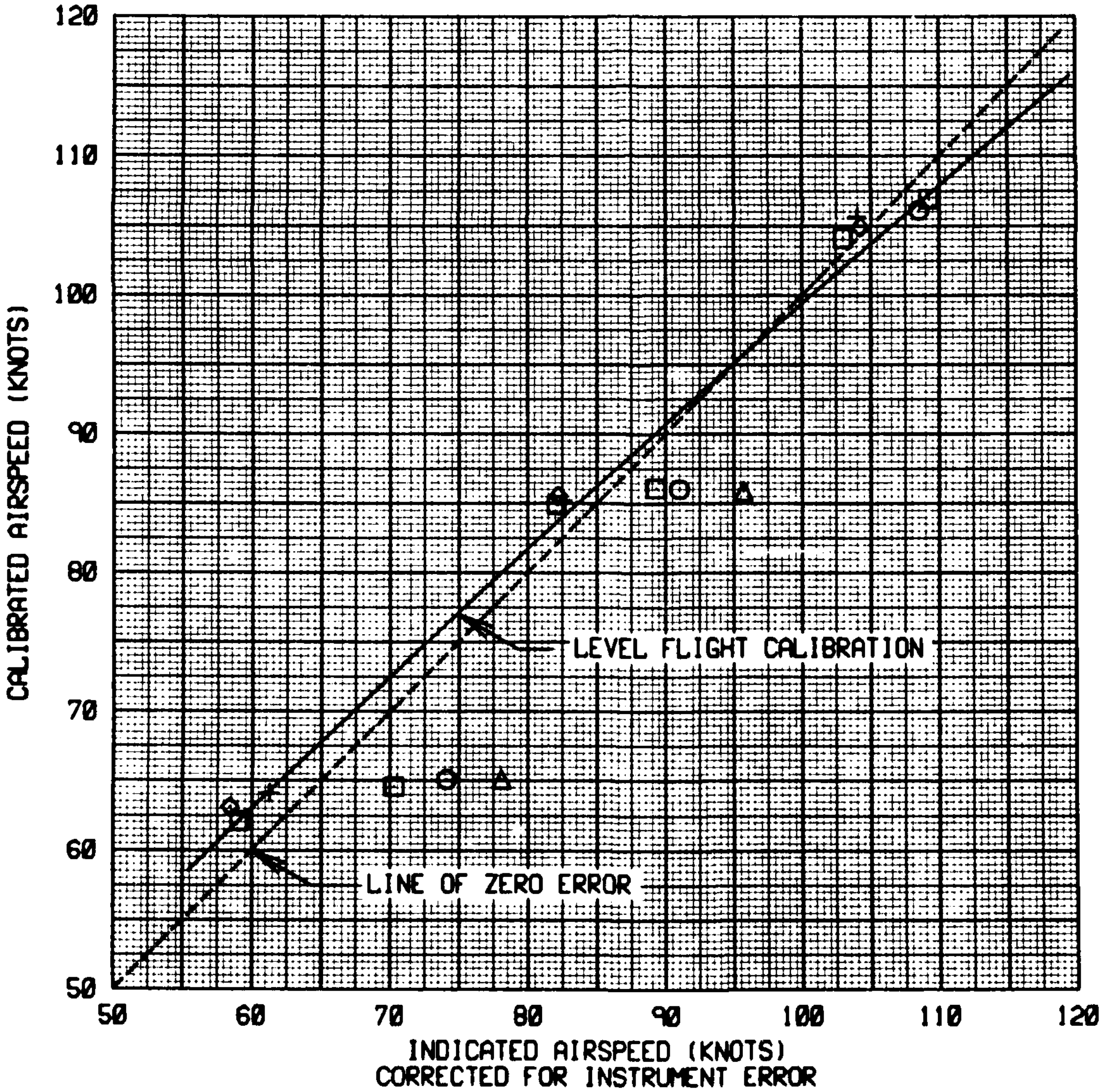


FIGURE E-22

COMPARISON OF SHIP AND BOOM SYSTEM AIRSPEEDS

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9470	198 6(AFT)	0.0	6000	9.5	321	86	CLIMB TO LEVEL

NOTE SCAS ON

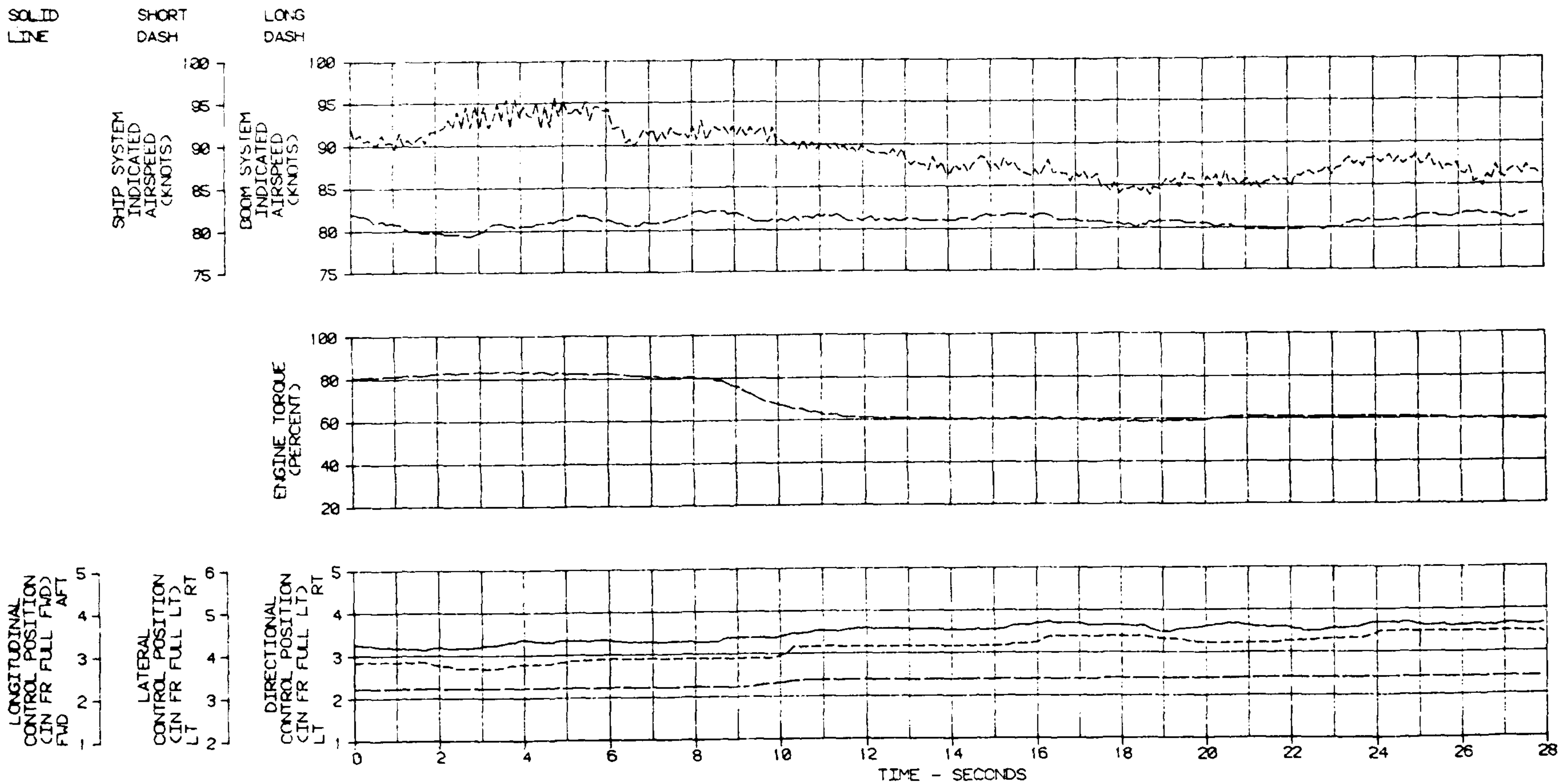


FIGURE E-23

INSTRUMENT TAKEOFF
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9820	199.4(AFT)	0.0	2860	15.5	321

NOTES
1. SIMULATED IMC FLIGHT
2. PRODUCTION SCAS MODULES
3. 0-0 (CEILING-VISIBILITY) PROCEDURE

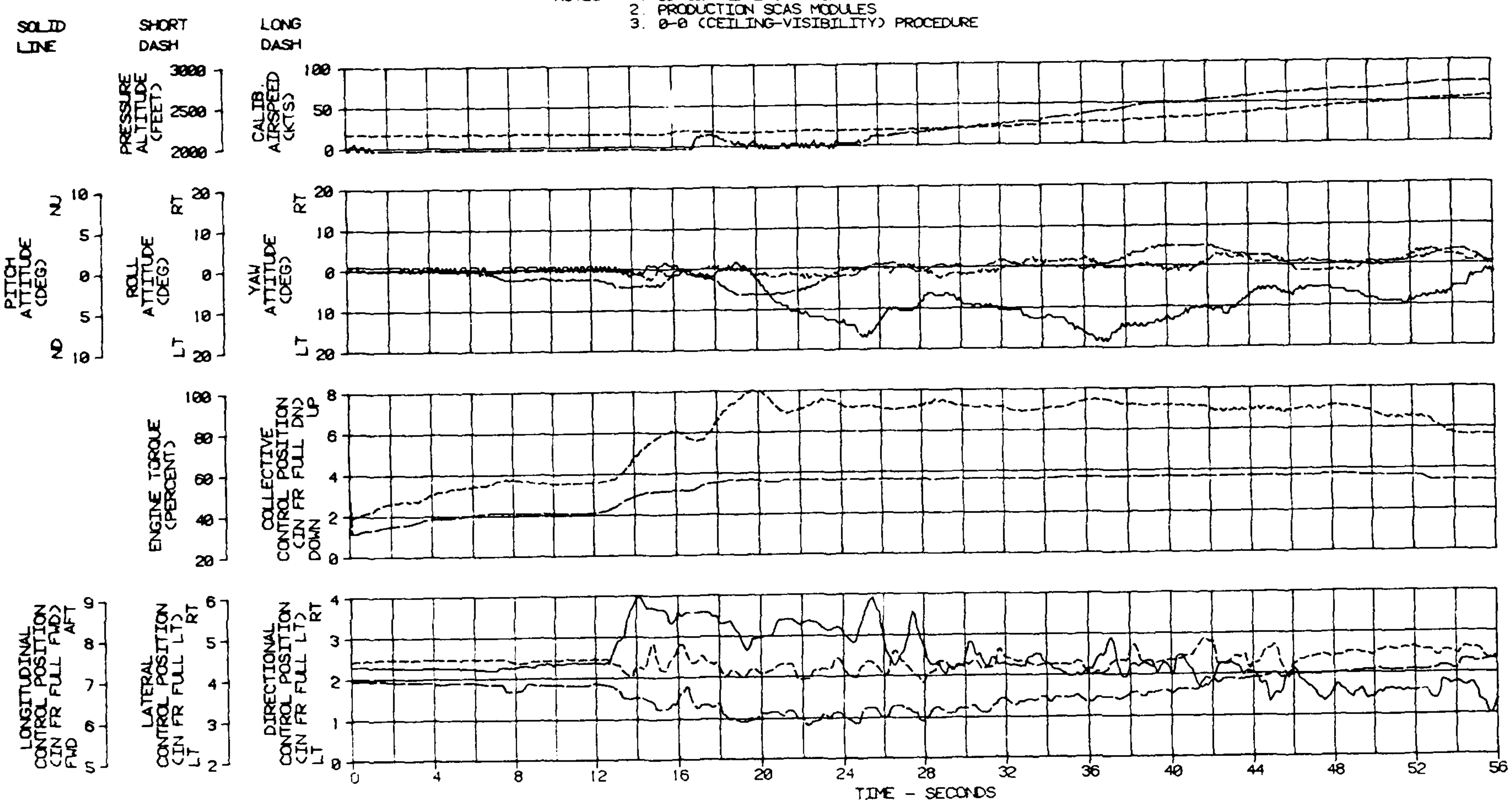


FIGURE E-24

INSTRUMENT TAKEOFF
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9890	199.4(AFT)	0.0	2860	14.5	322

NOTES
1. SIMULATED IMC FLIGHT
2. PRODUCTION SCAS MODULES
3. 100-1/4 (CEILING-VISIBILITY) PROCEDURE

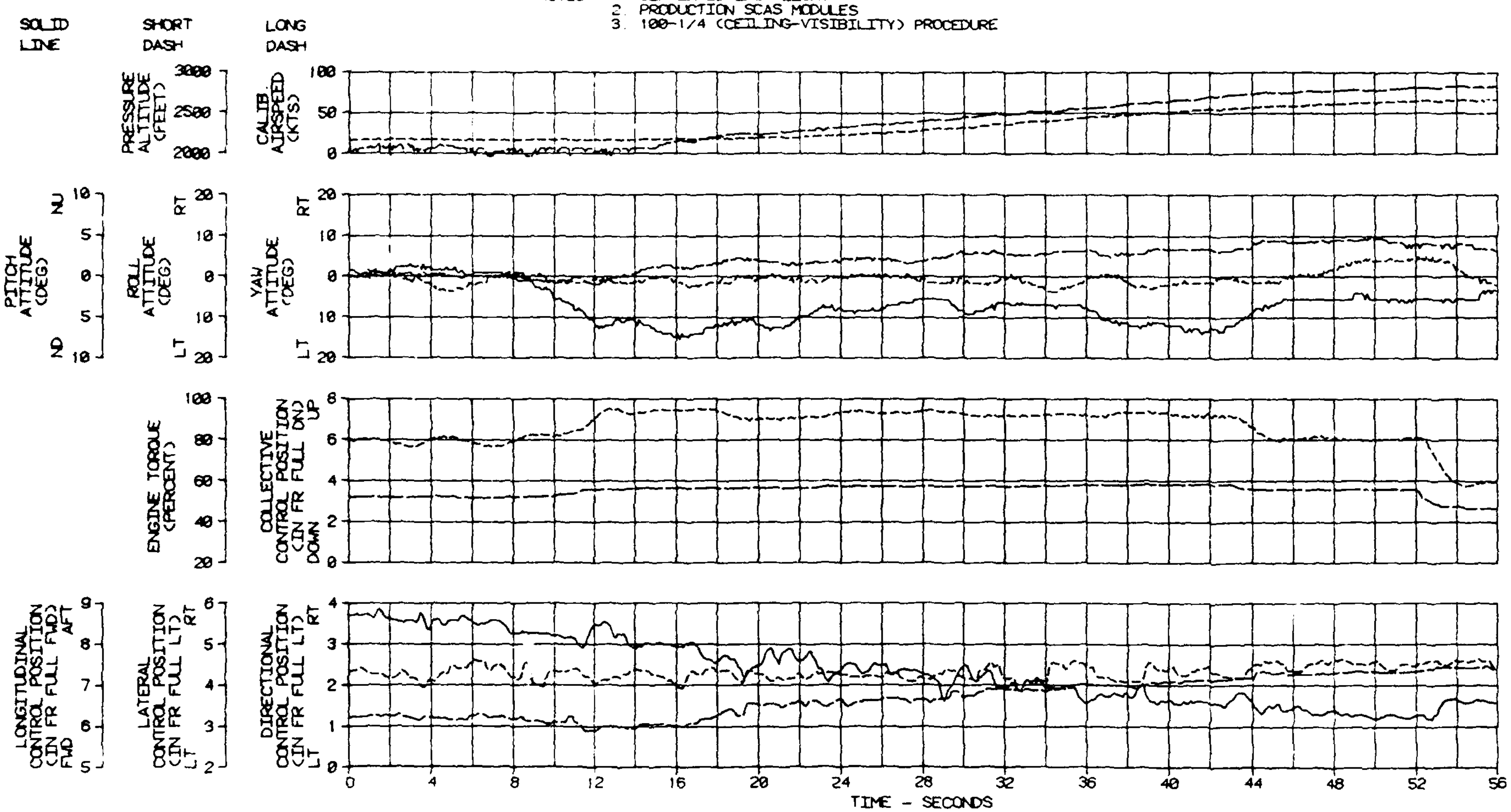


FIGURE E-25

AIR DATA SUBSYSTEM AIRSPEED CALIBRATION

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)
9670	198.8(AFT)	0.0	6660	12.0	323

NOTES: 1. BALL CENTERED FLIGHT
2. □ = 500 FPM CLIMB
○ = 1000 FPM CLIMB
△ = 1500 FPM CLIMB
+ = 500 FPM DESCENT
◇ = 1000 FPM DESCENT
□ = 1500 FPM DESCENT

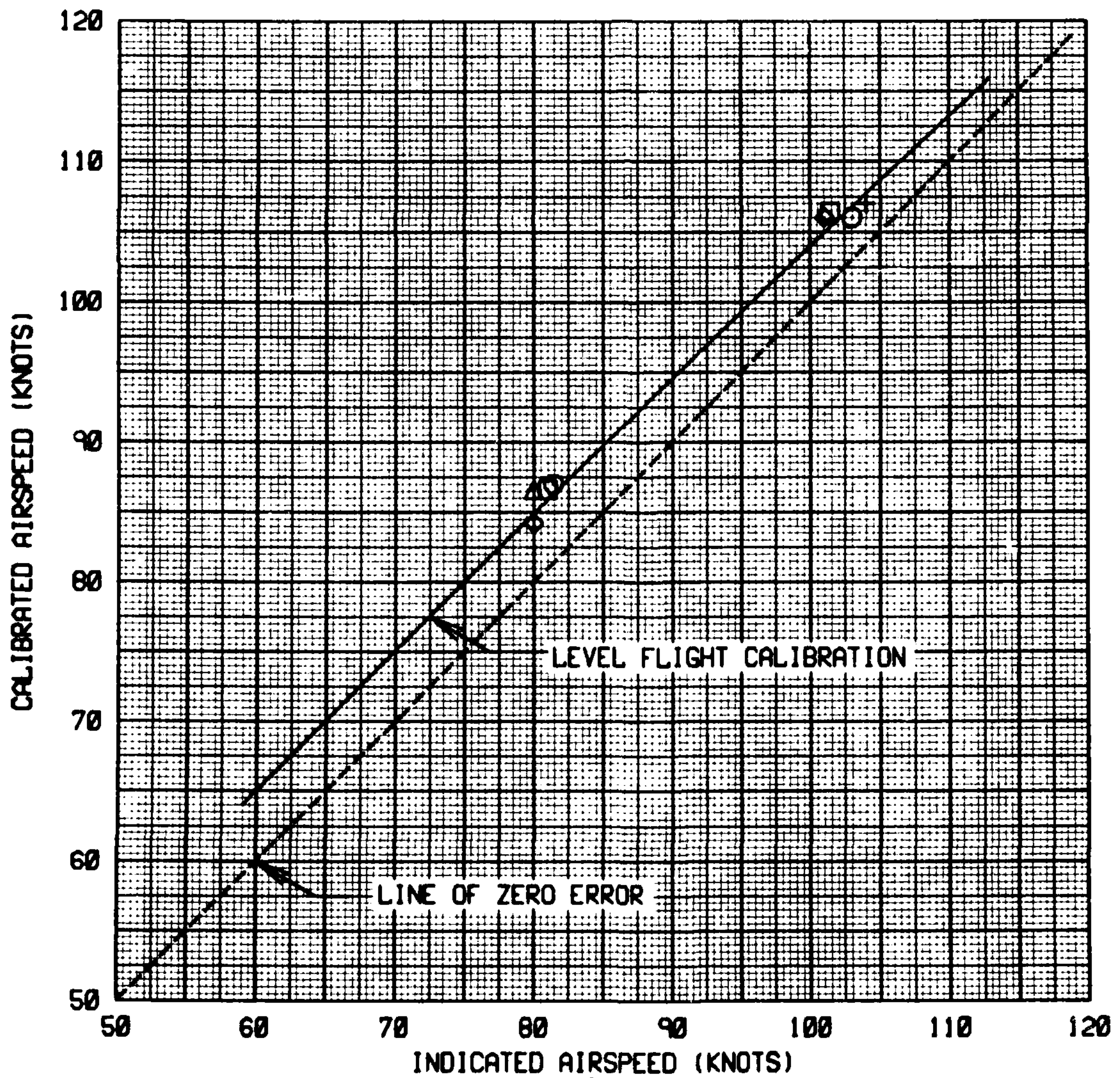


FIGURE E-26

LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
PILOT STATION
AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LATERAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.2 LB AFT
   1.0 LB FORWARD
7. CENTERING SPRING PRELOAD 3.0 LB
8. AVERAGE FORCE GRADIENT 1.7 LB/IN

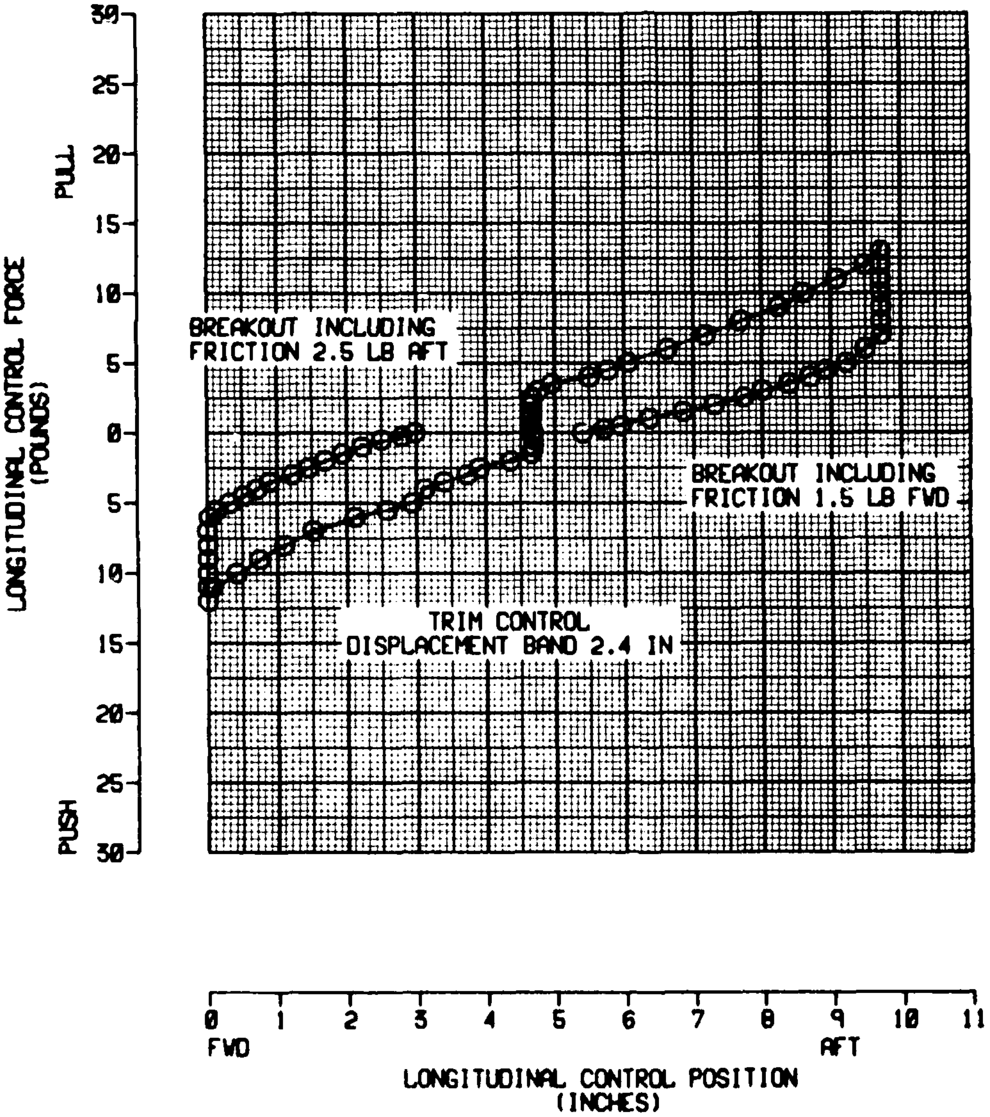


FIGURE E-27

LATERAL CONTROL SYSTEM CHARACTERISTICS
PILOT STATION

AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LONGITUDINAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.0 LB LEFT
   1.1 LB RIGHT
7. CENTERING SPRING PRELOAD 3.0 LB
8. AVERAGE FORCE GRADIENT 1.4 LB/IN

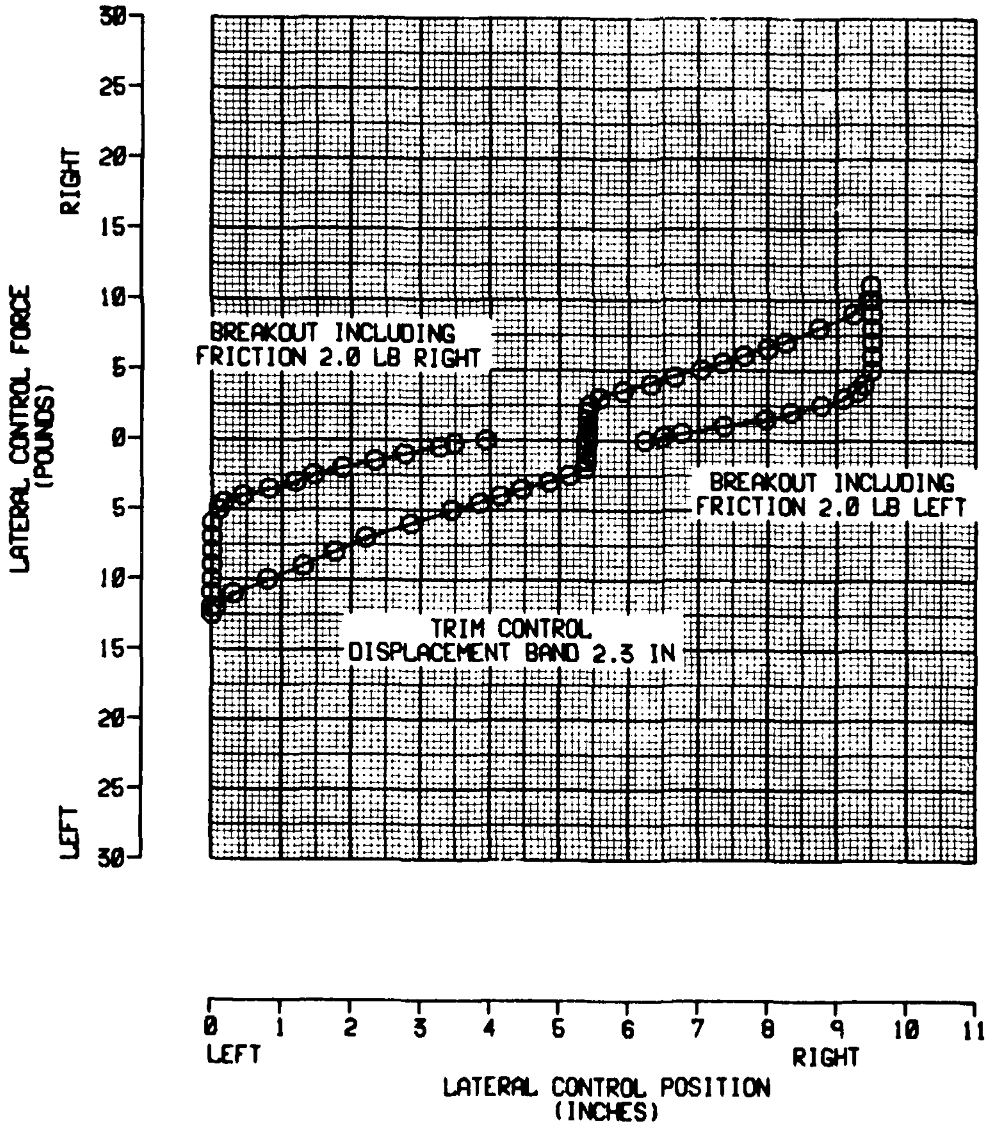


FIGURE E-28

LONGITUDINAL CONTROL SYSTEM CHARACTERISTICS
COPILOT/GUNNER STATION

AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LATERAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.2 LB AFT
   1.0 LB FORWARD
7. CENTERING SPRING PRELOAD 3.0 LB
8. AVERAGE FORCE GRADIENT 4.5 LB/IN

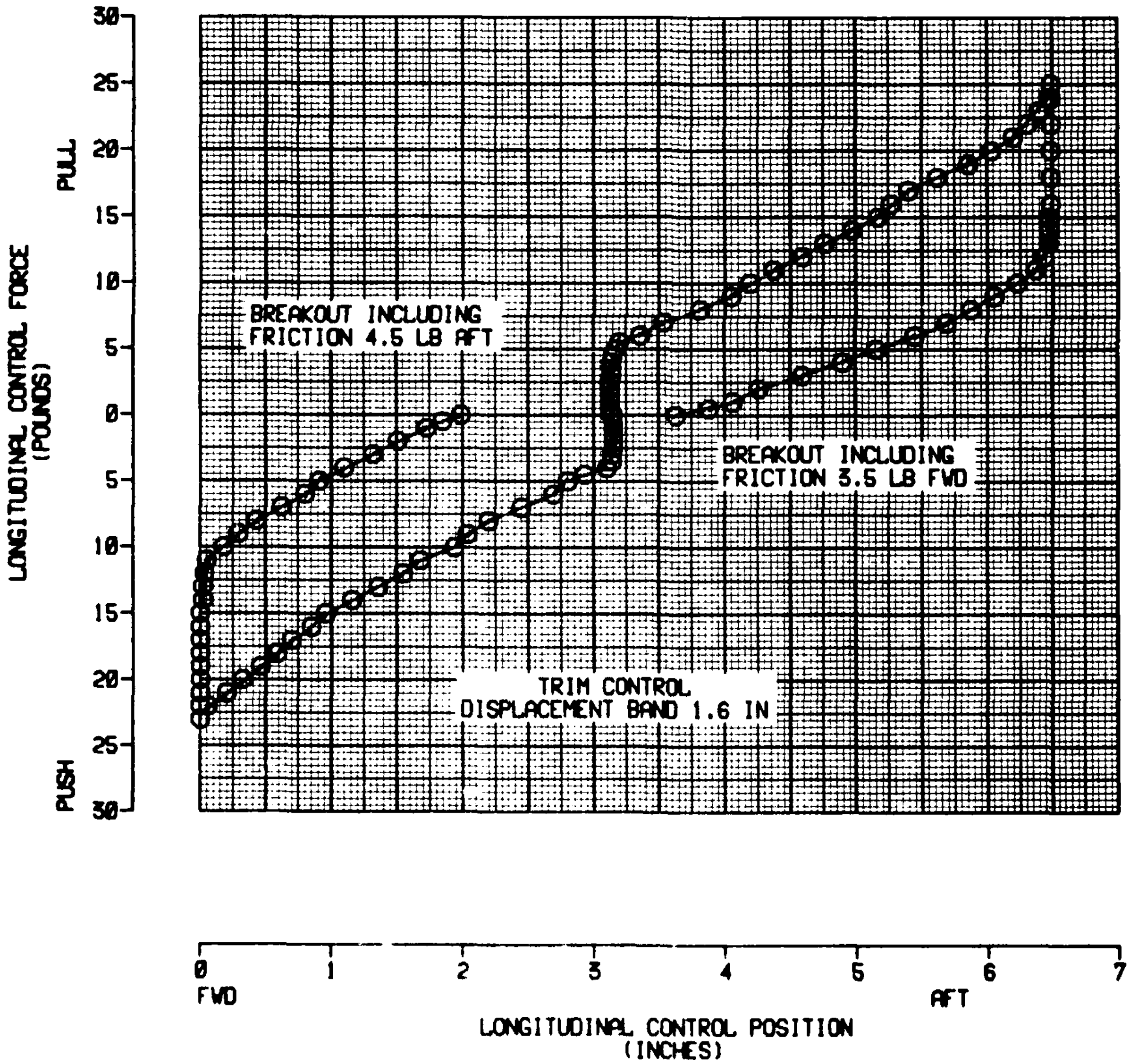


FIGURE E-29

LATERAL CONTROL SYSTEM CHARACTERISTICS
COPILOT/GUNNER STATION

AH-1F USA S/N 69-16423

NOTES:
1. ROTOR STATIC
2. HYDRAULIC AND ELECTRICAL POWER PROVIDED BY GROUND POWER UNITS
3. LONGITUDINAL CONTROL CENTERED DURING TEST
4. CONTROL FORCES MEASURED AT CENTER OF GRIP
5. FORCE TRIM ON
6. PRESET FRICTION 1.0 LB LEFT
   1.1 LB RIGHT
7. CENTERING SPRING PRELOAD 3.0 LB
8. AVERAGE FORCE GRADIENT 4.5 LB/IN

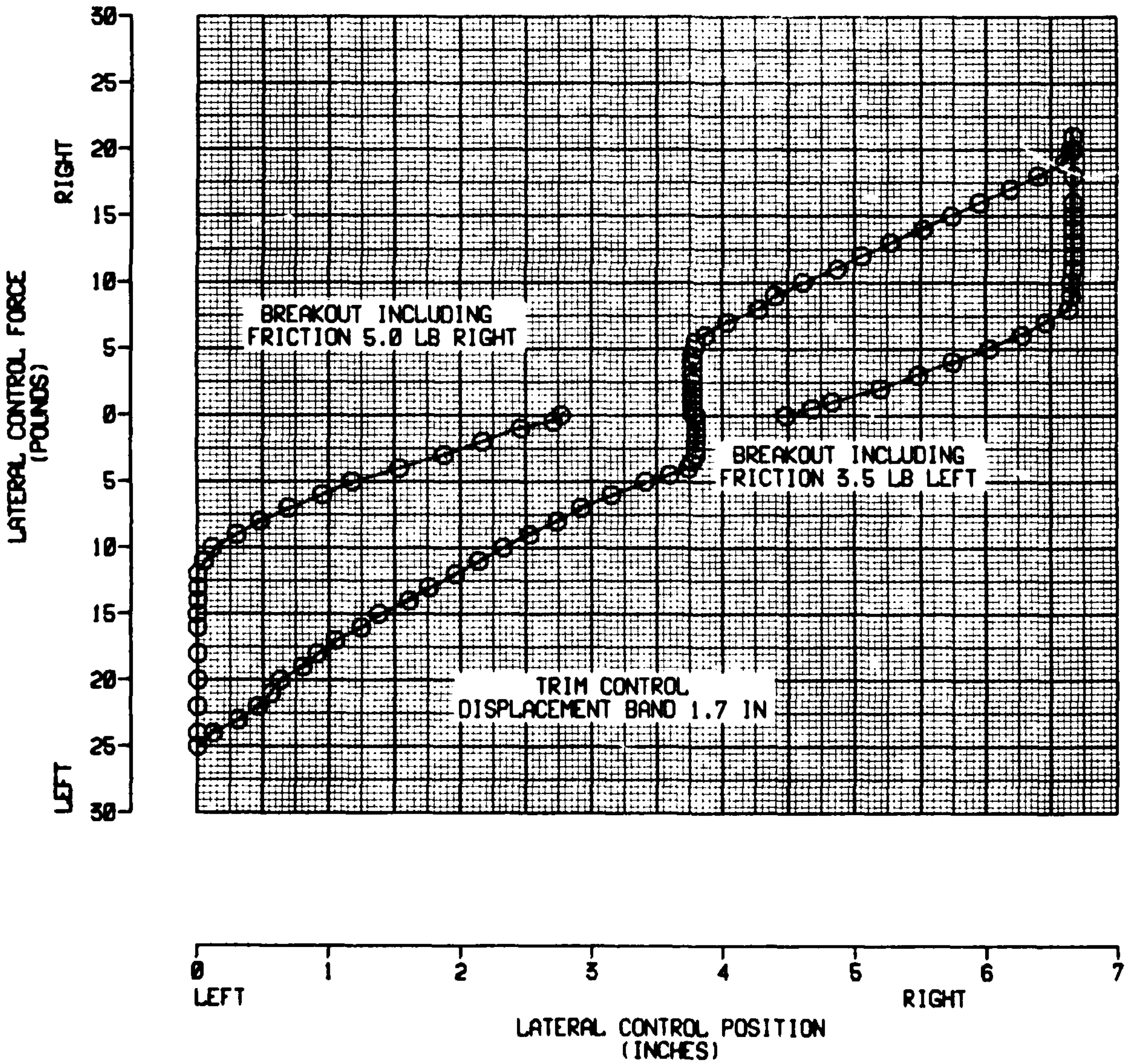


FIGURE E-30

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9160	200.1(AFT)	0.0	5630	26.0	324	LEVEL

NOTES:
1. BALL CENTERED FLIGHT
2. SCAS ON
3. GURNEY FLAP CONFIGURATION

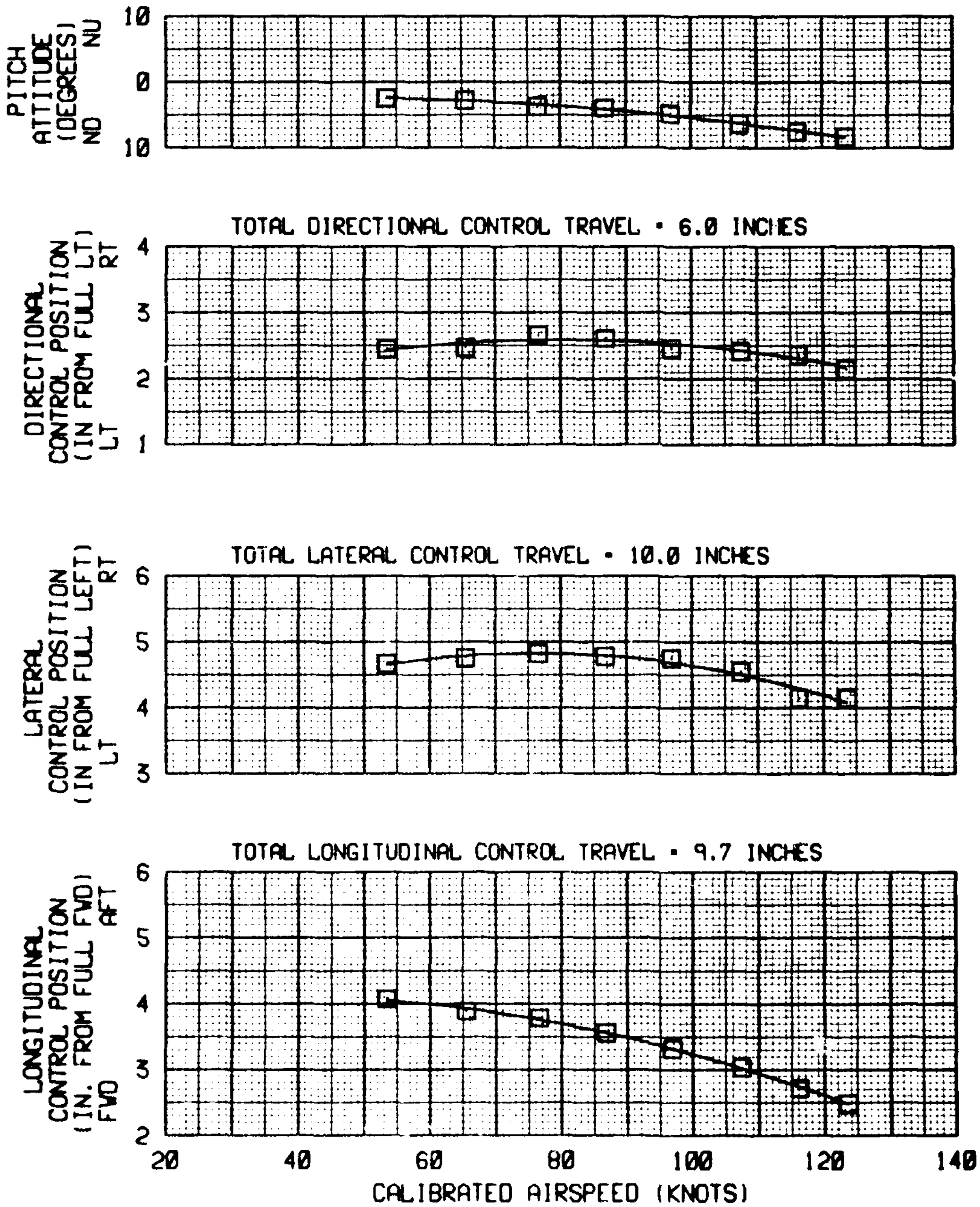


FIGURE E-31

STATIC LATERAL-DIRECTIONAL STABILITY

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
9370	199.8(AFT)	0.0	5230	26.5	324	116

NOTES: 1. SHADED POINT DENOTES BALL CENTERED FLIGHT
2. SCAS ON
3. GURNEY FLAP CONFIGURATION

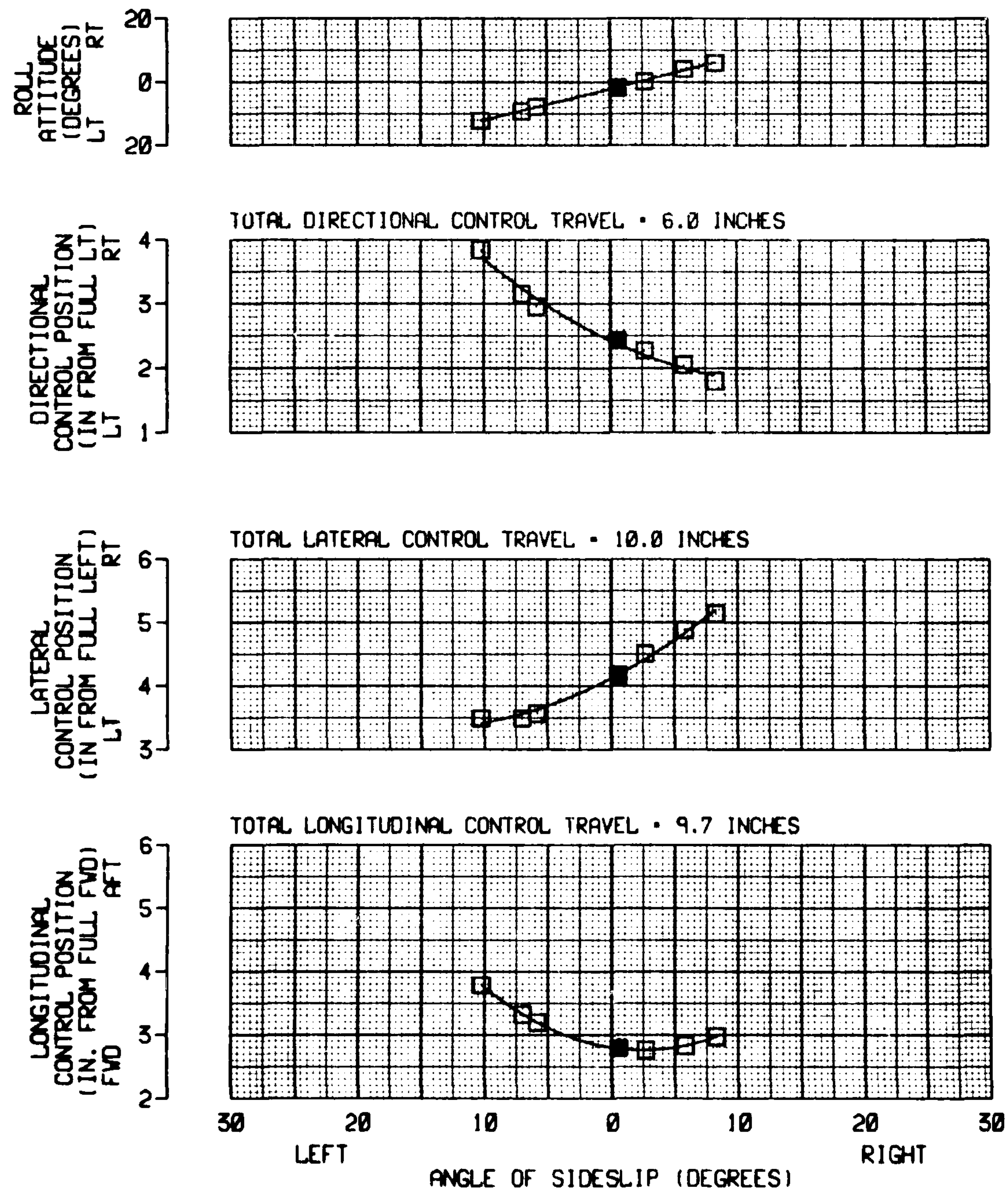


FIGURE E-32

LEFT LATERAL PULSE

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9310	200.0(AFT)	0.0	6580	23.5	323	116	LEVEL

NOTES: 1. SCAS ON
2. GURNEY FLAP INSTALLED

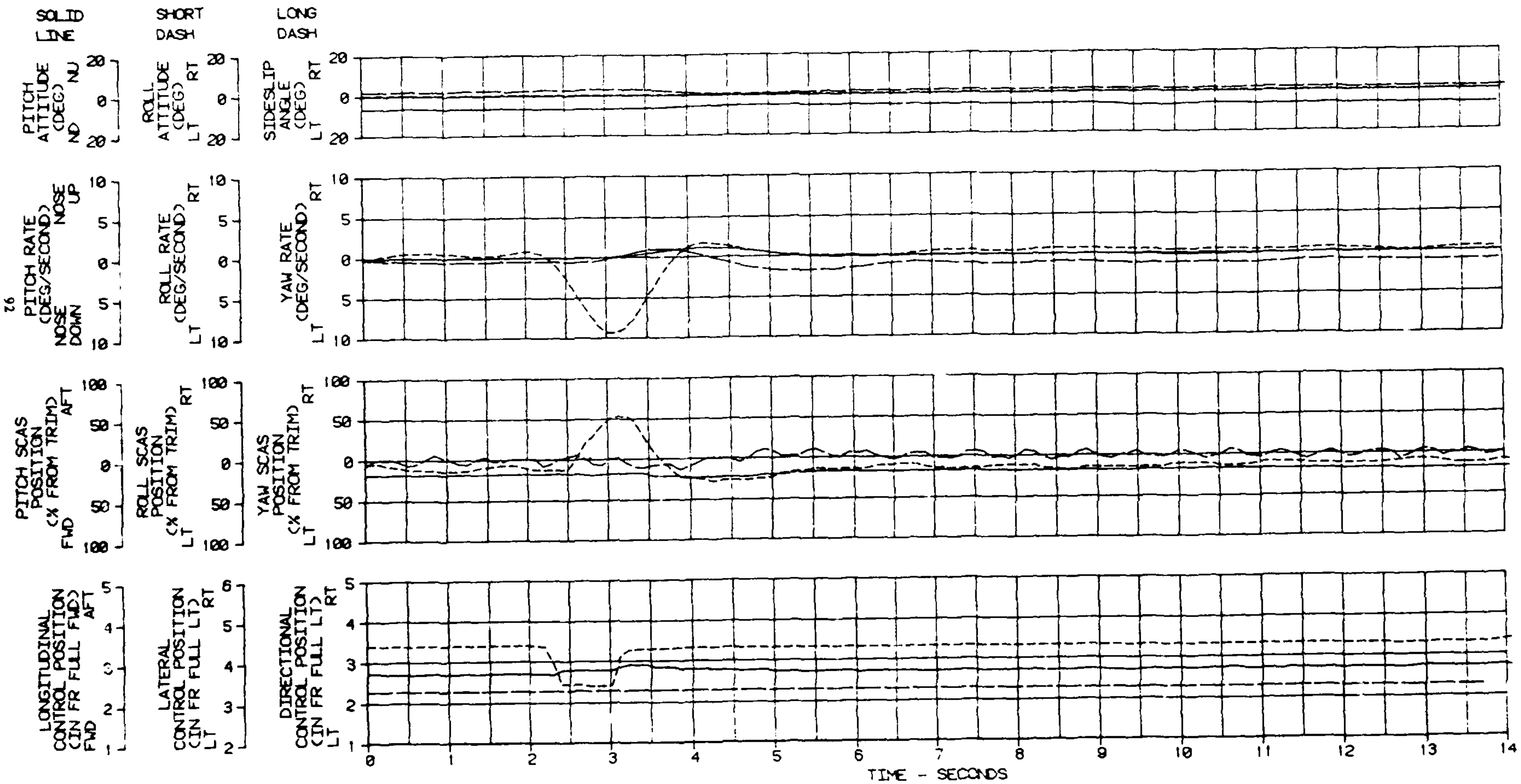


FIGURE E-33

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9780	199.1(AFT)	0.0	4750	6.0	323	LEVEL

NOTES: 1. BALL CENTERED FLIGHT
2. SCAS ON
3. VENTRAL FIN CONFIGURATION

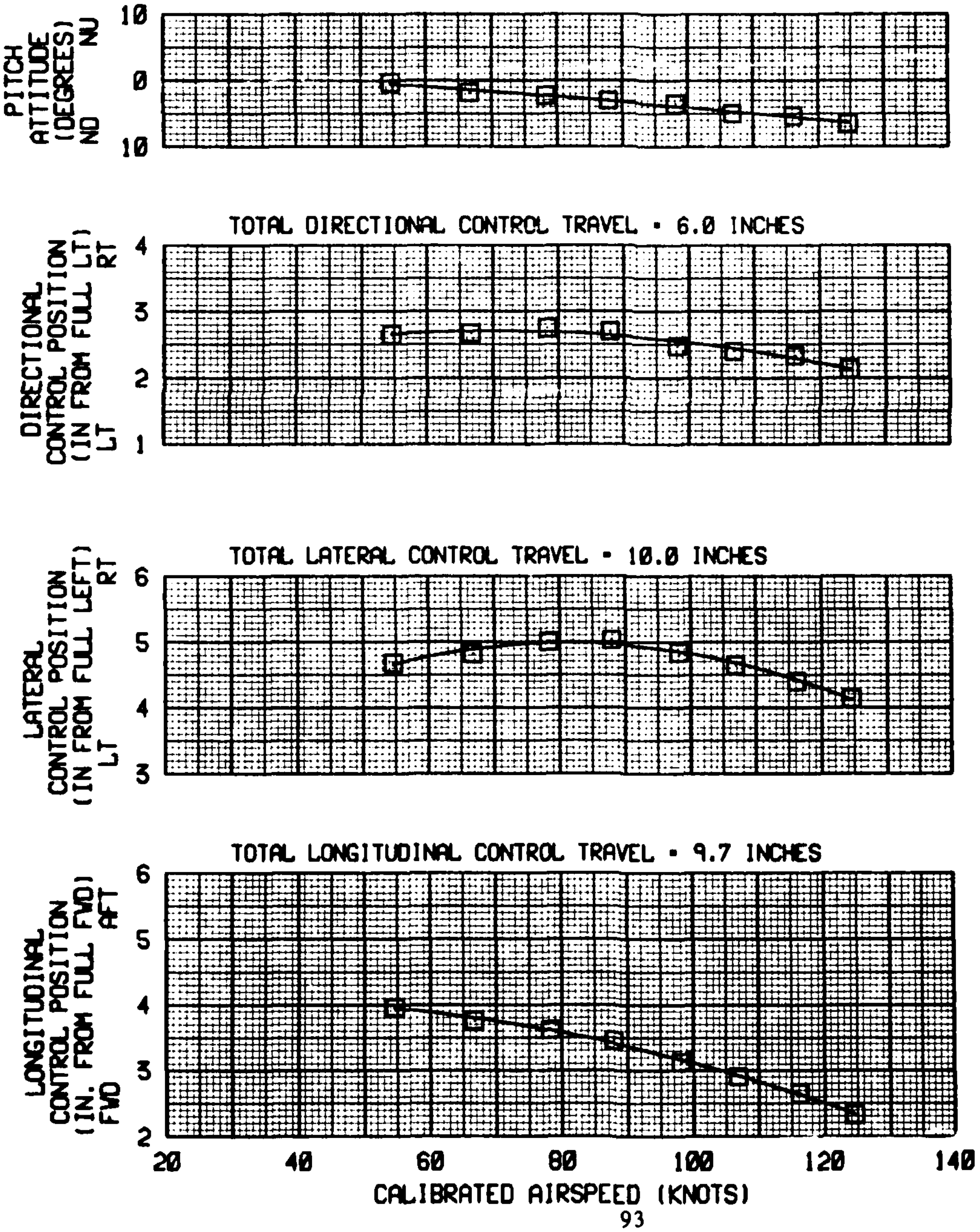


FIGURE E-34

STATIC LATERAL-DIRECTIONAL STABILITY

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
9420	199.1(AFT)	0.0	4240	7.0	323	115

NOTES:
1. SHADED POINT DENOTES BALL CENTERED FLIGHT
2. SCAS ON
3. VENTRAL FIN CONFIGURATION

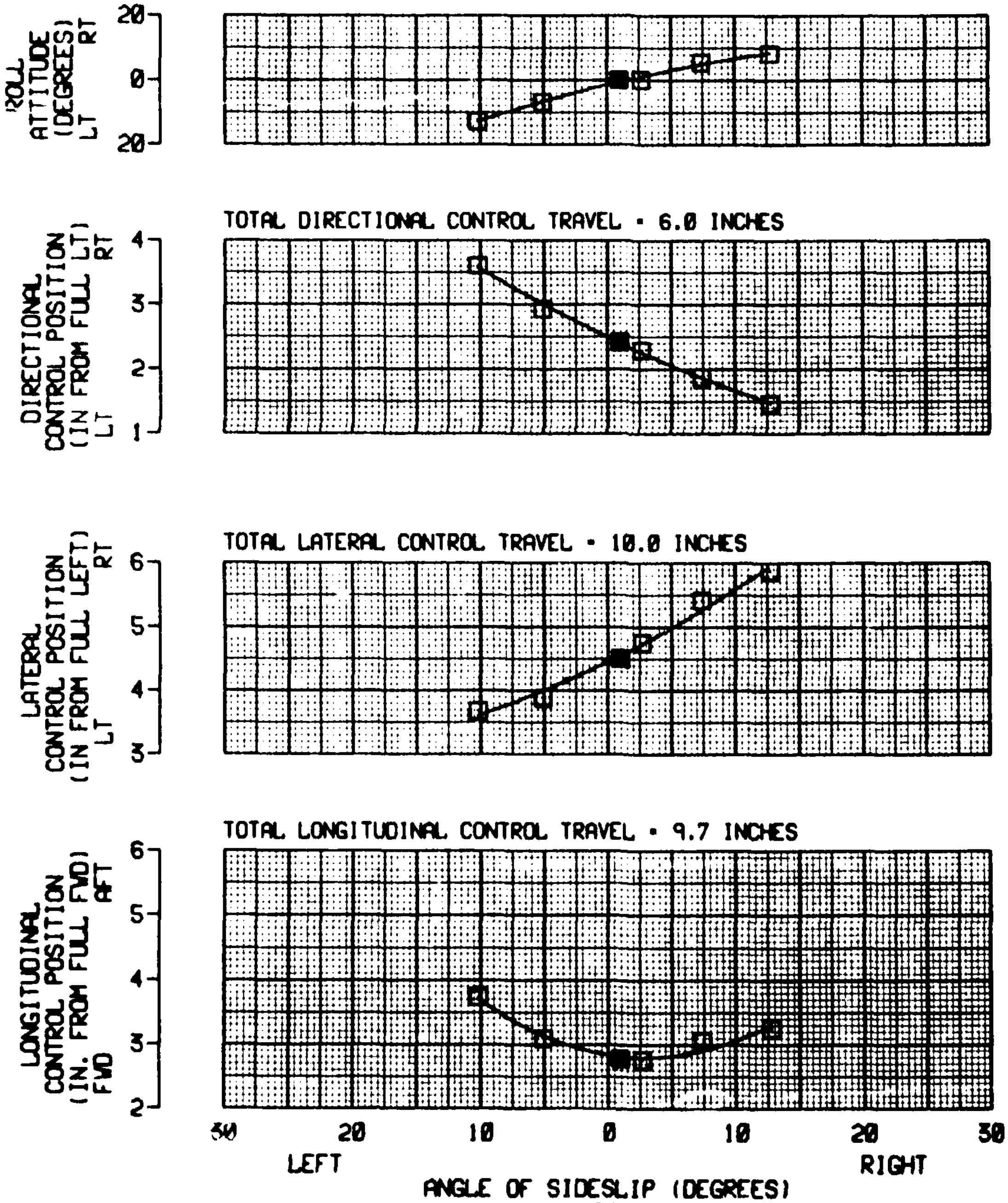


FIGURE E-35

RELEASE FROM LEFT SIDESLIP
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9560	199 1(AFT)	0.0	5120	6 0	323	86	LEVEL

NOTES: 1. SCAS ON
2. VENTRAL FIN CONFIGURATION

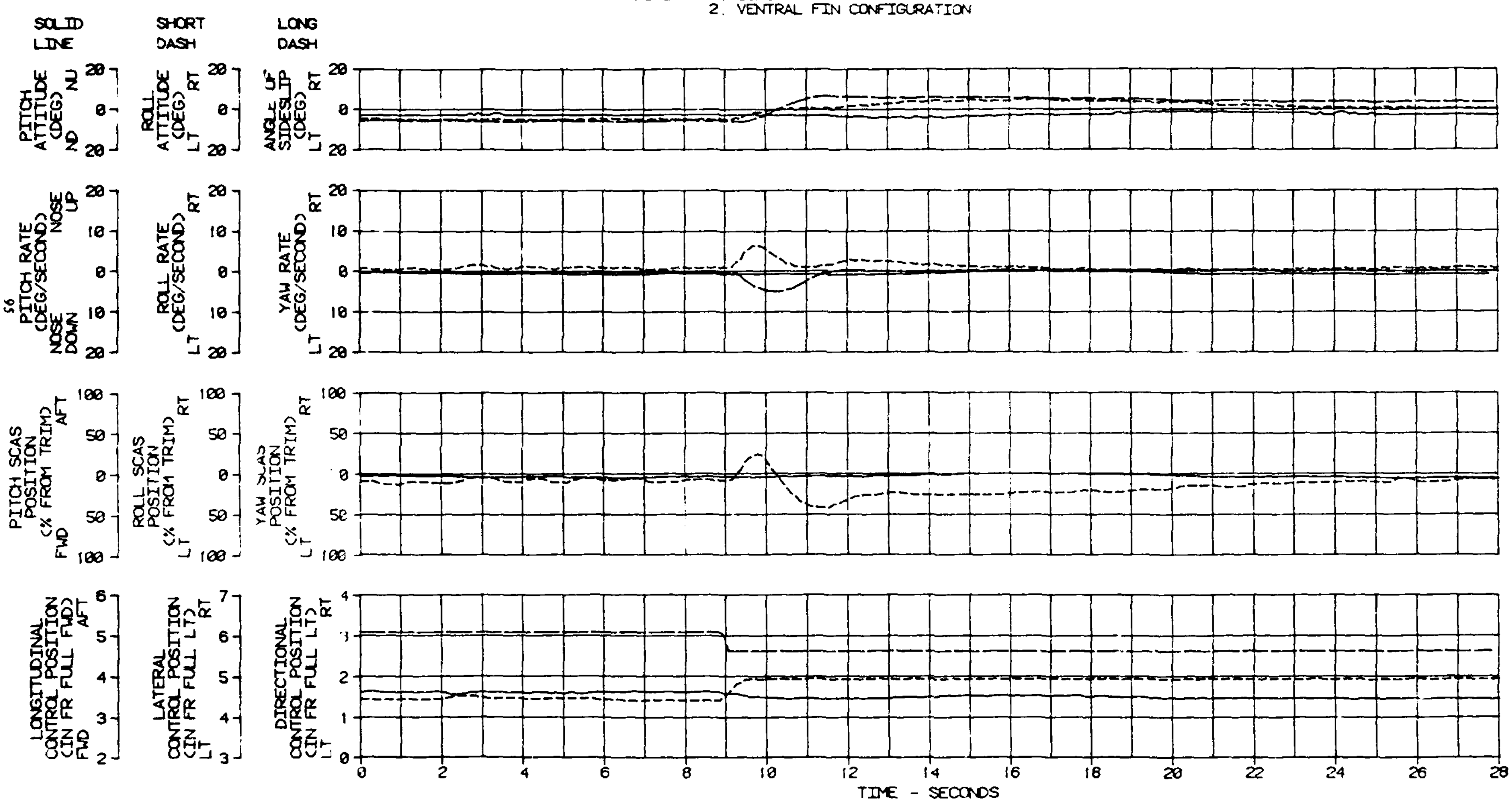


FIGURE E-36

RIGHT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9350	199 4(AFT)	0 0	5810	15 5	322	106	LEVEL

NOTES:
1. SCAS ON
2. MODIFIED PITCH AND ROLL SCAS MODULES
3. PITCH ATTITUDE HOLD OFF
4. ROLL ATTITUDE HOLD OFF

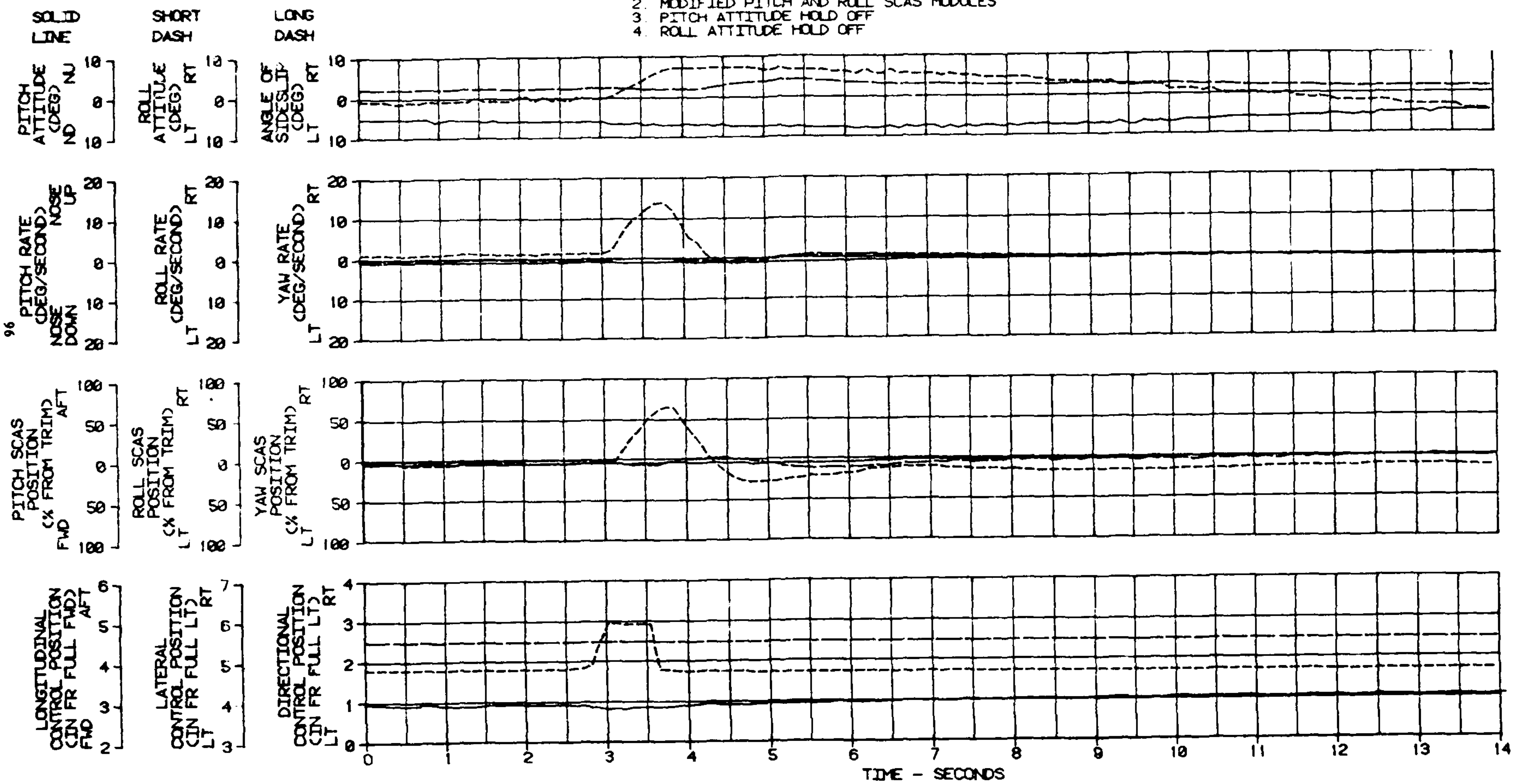


FIGURE E-37

RIGHT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9310	199.4(AFT)	0.0	6030	15.0	322	106	LEVEL

NOTES: 1. SCAS ON
2. MODIFIED PITCH AND ROLL SCAS MODULES
3. PITCH ATTITUDE HOLD OFF
4. ROLL ATTITUDE HOLD ON

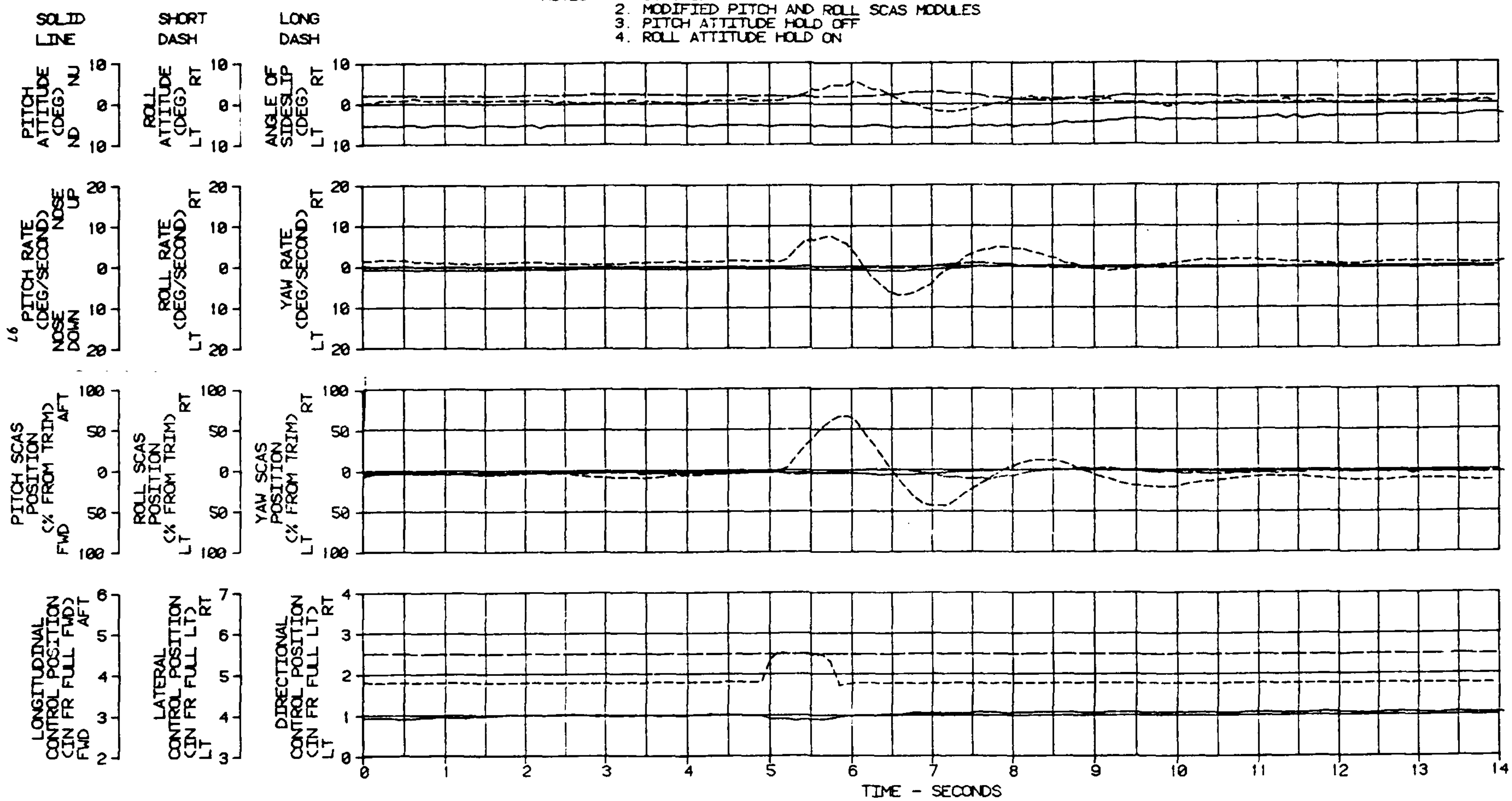


FIGURE E-38

STATIC LONGITUDINAL STABILITY
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	FLIGHT CONDITION
9820	199.4(AFT)	0.0	5020	8.0	321	LEVEL

NOTES: 1. SHADED SYMBOLS DENOTE TRIM
2. PITCH ATTITUDE HOLD ON
3. ROLL ATTITUDE HOLD ON

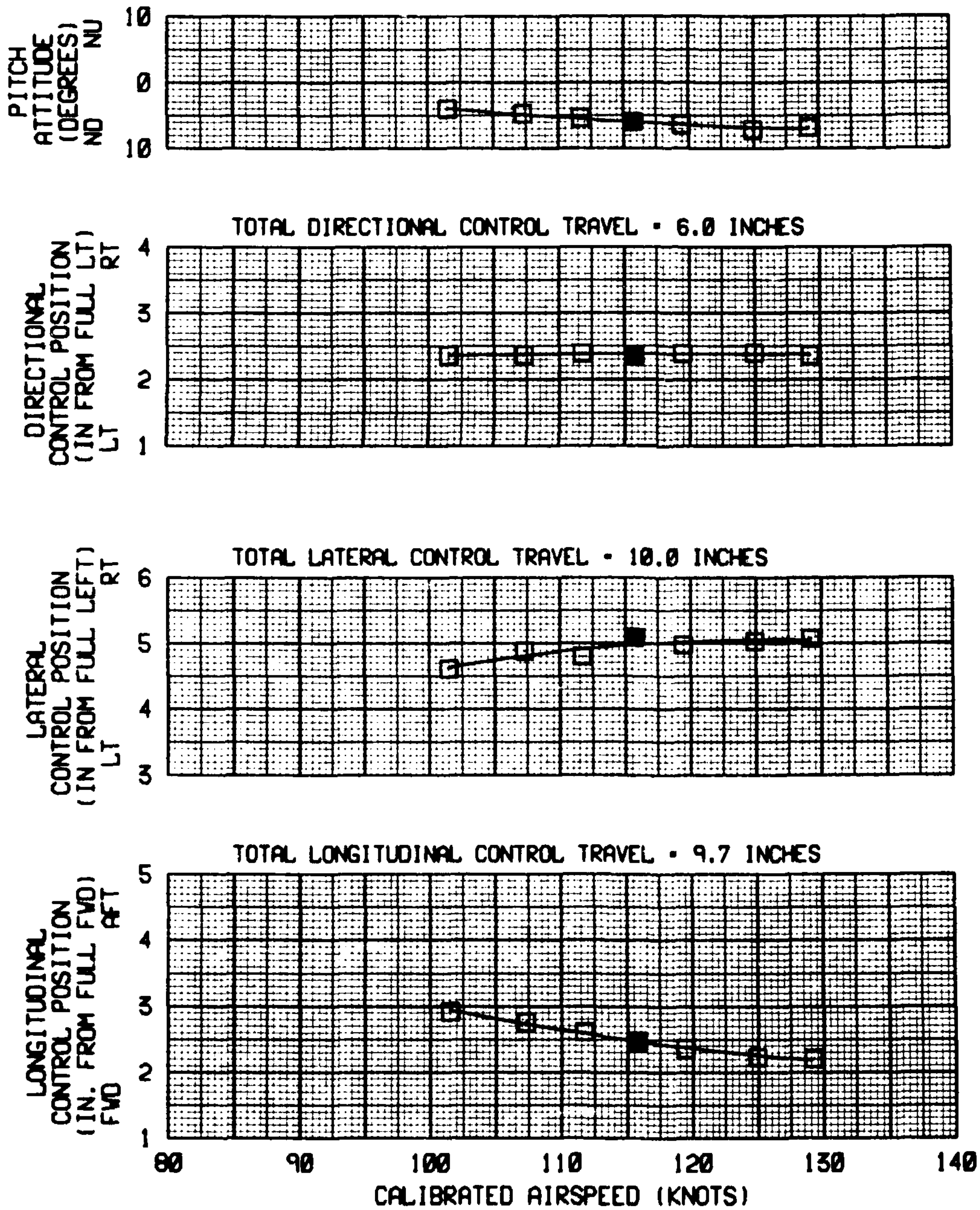


FIGURE E-39

STATIC LATERAL-DIRECTIONAL STABILITY

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
9430	199.4(AFT)	0.0	4070	8.0	32:	116

NOTES: 1. SHADED POINT DENOTES BALL CENTERED FLIGHT
2. PITCH ATTITUDE HOLD ON
3. ROLL ATTITUDE HOLD ON

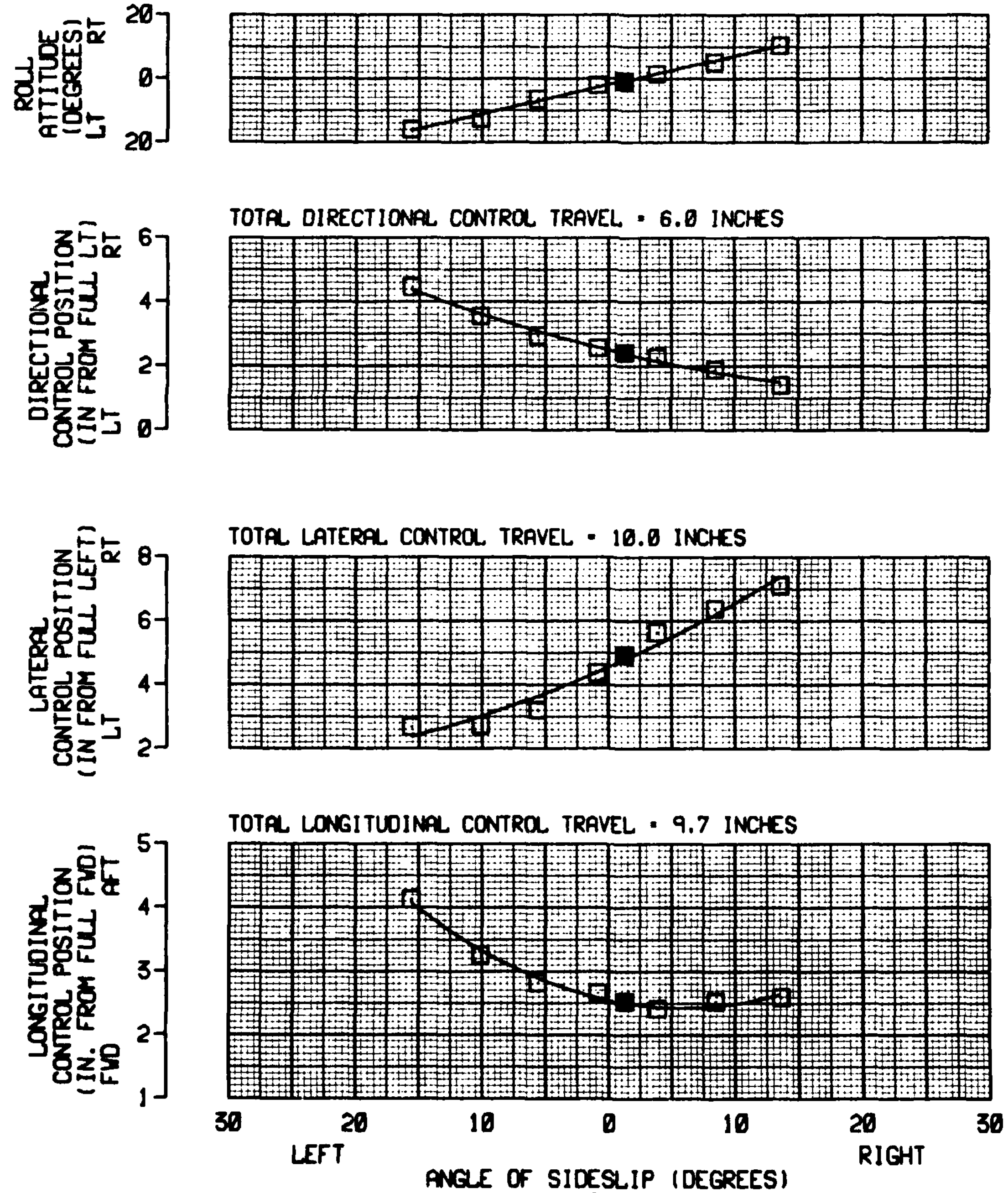


FIGURE E-40

FORWARD LONGITUDINAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9600	199.4(AFT)	0.0	5400	7.5	321	116	LEVEL

NOTES: 1. SCAS ON
2. PITCH ATTITUDE HOLD ON
3. ROLL ATTITUDE HOLD ON

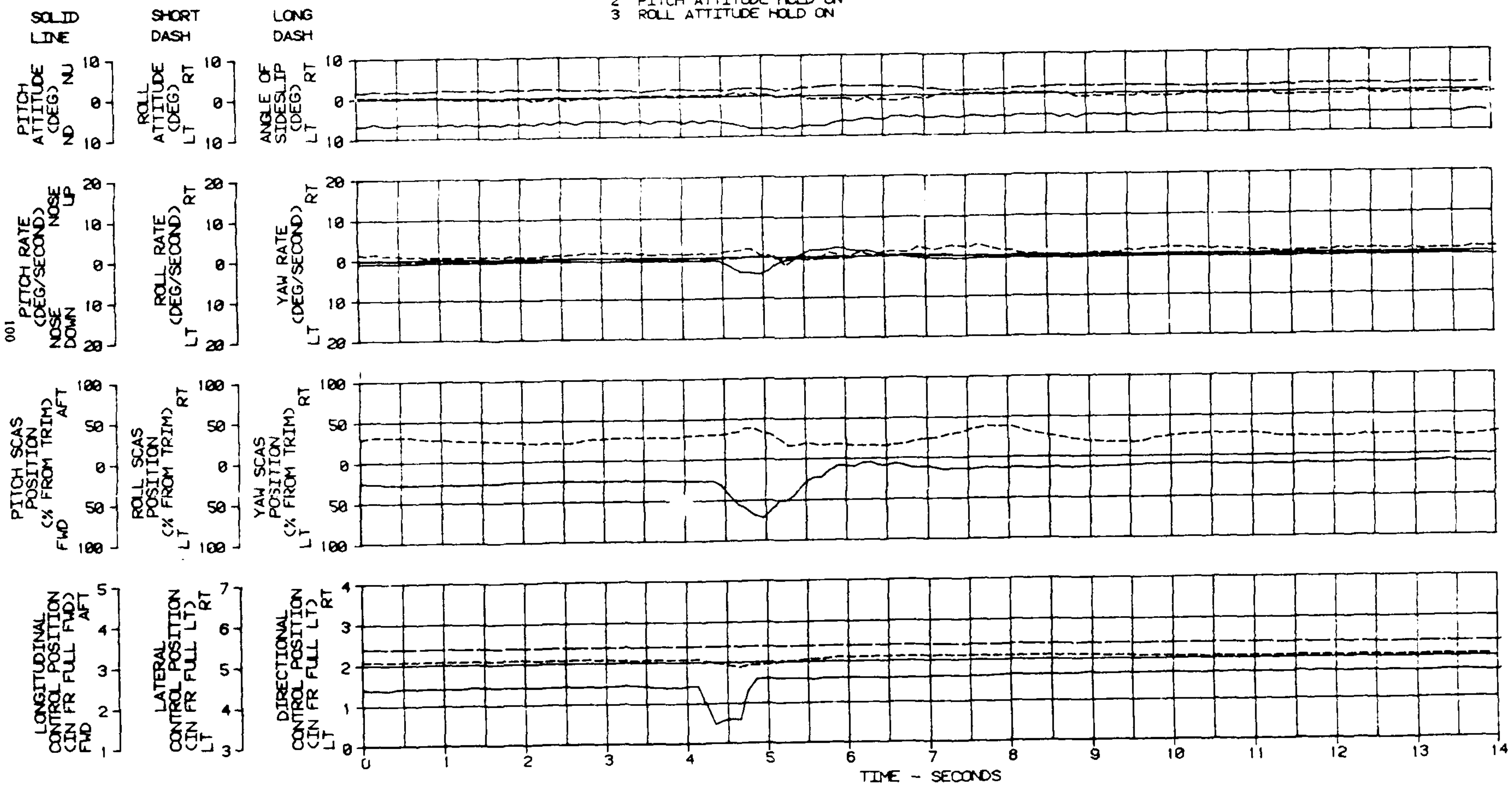


FIGURE E-41

RIGHT LATERAL PULSE
AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KT)	FLIGHT CONDITION
9230	199.4(AFT)	0.0	5540	8.0	321	116	LEVEL

NOTES: 1. SCAS ON
2. PITCH ATTITUDE HOLD ON
3. ROLL ATTITUDE HOLD ON

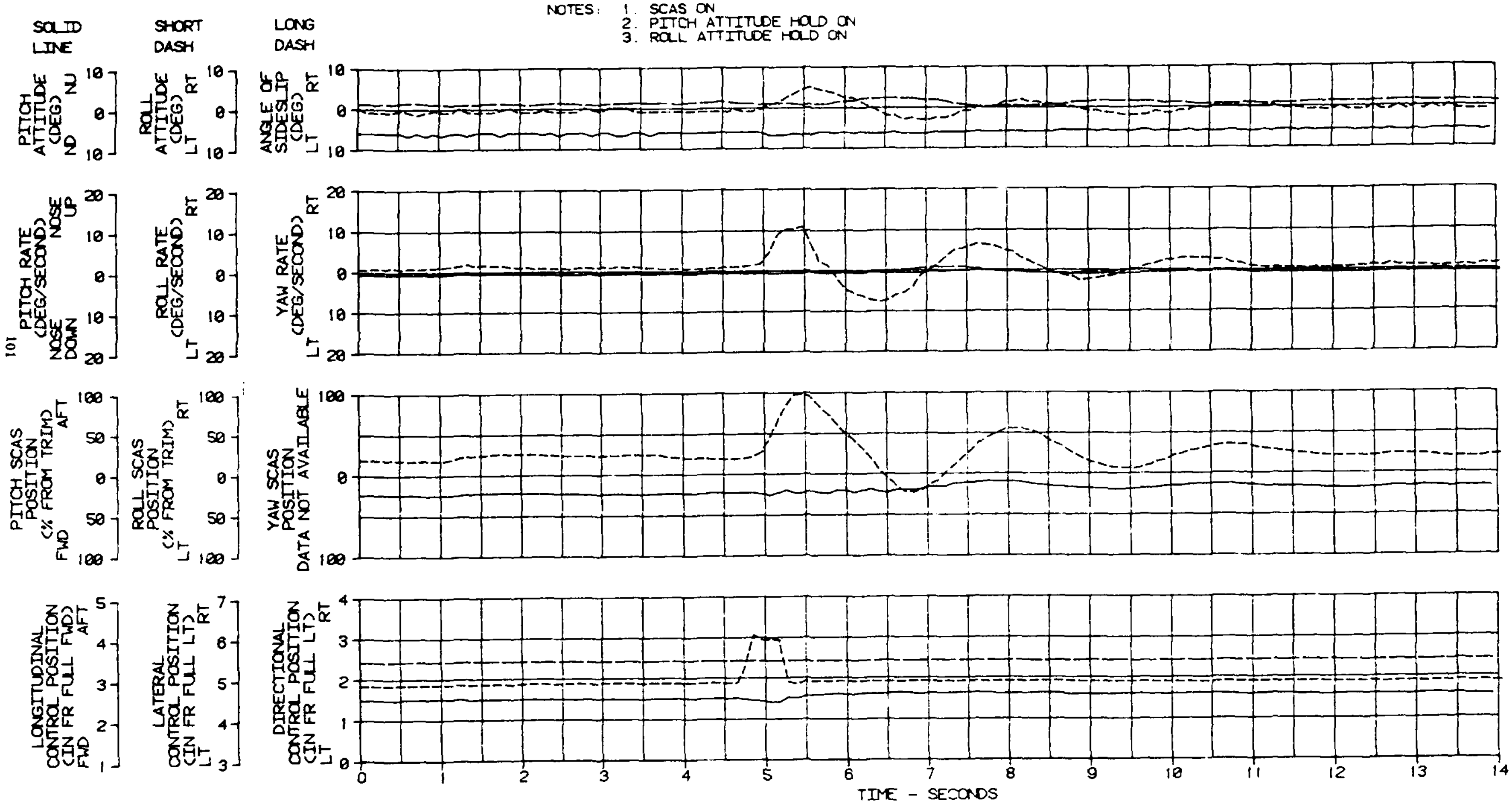


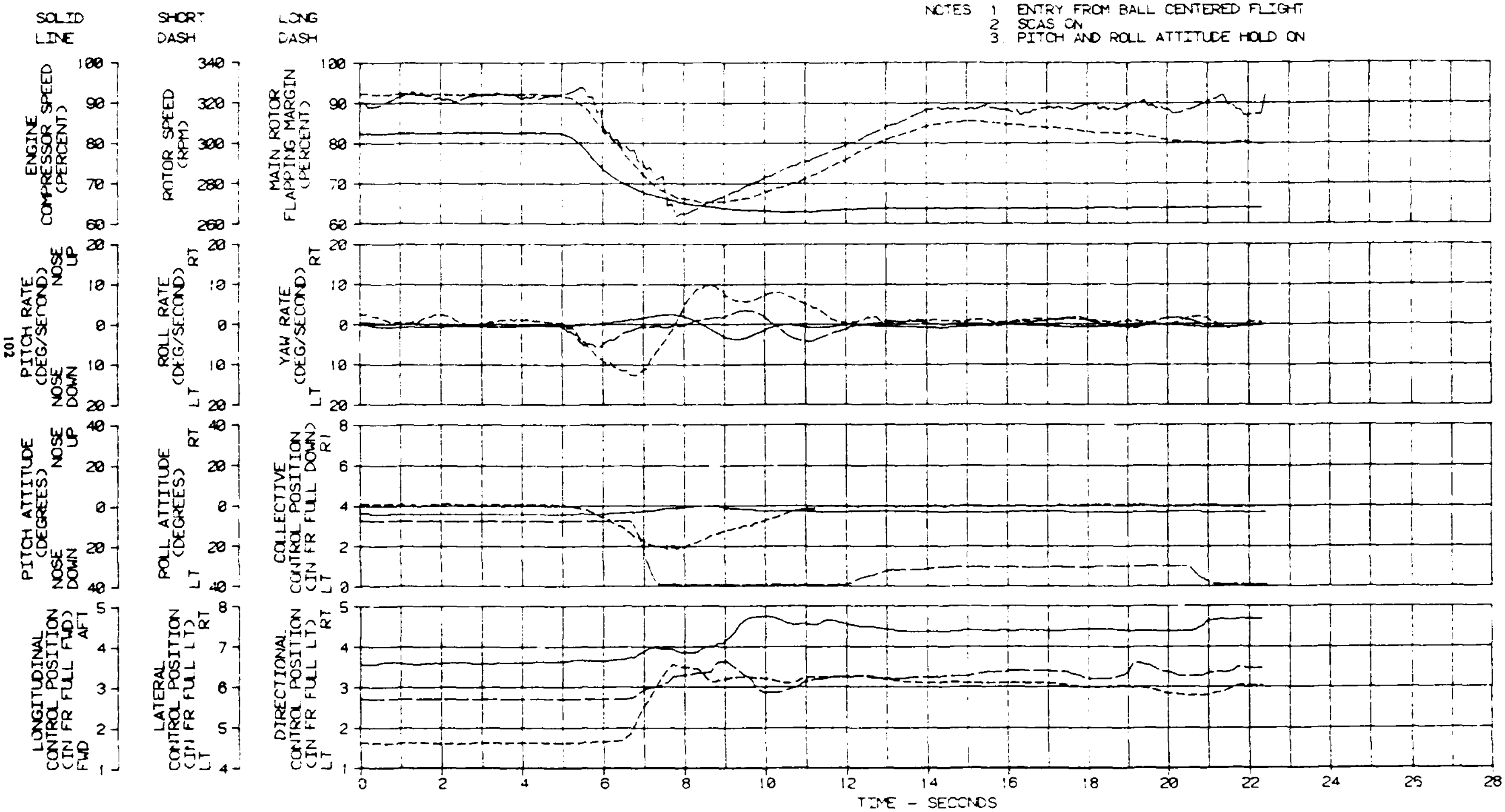
FIGURE E-42

SIMULATED ENGINE FAILURE

AH-1F USA S/N 69-16423

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	ENTRY ROTOR SPEED (RPM)	ENTRY CALIBRATED AIRSPEED (KT)	ENTRY ENGINE TORQUE (PERCENT)	FLIGHT CONDITION
9390	199.5(AFT)	0.0	5540	-5.5	324	102	62	LEVEL

NOTES: 1. ENTRY FROM BALL CENTERED FLIGHT
2. SCAS ON
3. PITCH AND ROLL ATTITUDE HOLD ON



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